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Final Report

on

Contract Number NAS8-29100

WATER RESOURCES PLANNING FOR RIVERS DRAINING INTO MOBILE BAY

by
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Donald O. Hill, research assistant
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December 1976

NOTATION

The following symbols are used in this paper:

b	Bottom
C	Concentration of Species in the Water Column, M/L^3
D	Depth of Water in the Bay, L
E	Rate of Mass Transfer by Evaporation, L/T
	Dispersion Coefficient, L^2/T
f	Bay Bottom Friction Factor
g	Gravitational Acceleration, L/T^2
H	Height of Water above a Cell Datum, L
K	Constants
o	Source or Sink Term
Q	Discharge Rate, L^2/T
R	Rate of Mass Transfer by Rainfall, L/T
	Rate of Disappearance or Appearance of Mass, M/L^3T
r	Resuspension
s	Settling
	Surface
t	Time, T
V	Resultant of the Velocity Vector, L/T
v	Local Grid Velocity, L/T
W	Angular Velocity of Earth, L/T
x	Distance (East-West), L
y	Distance (North-South), L
z	Wind Speed, L/T

NOTATION (Continued)

η	Wind Speed, L/T
θ	Temperature
φ	Wind Direction
ψ	Angle Measurement in the Coriolis Term
∂	Differential Operation

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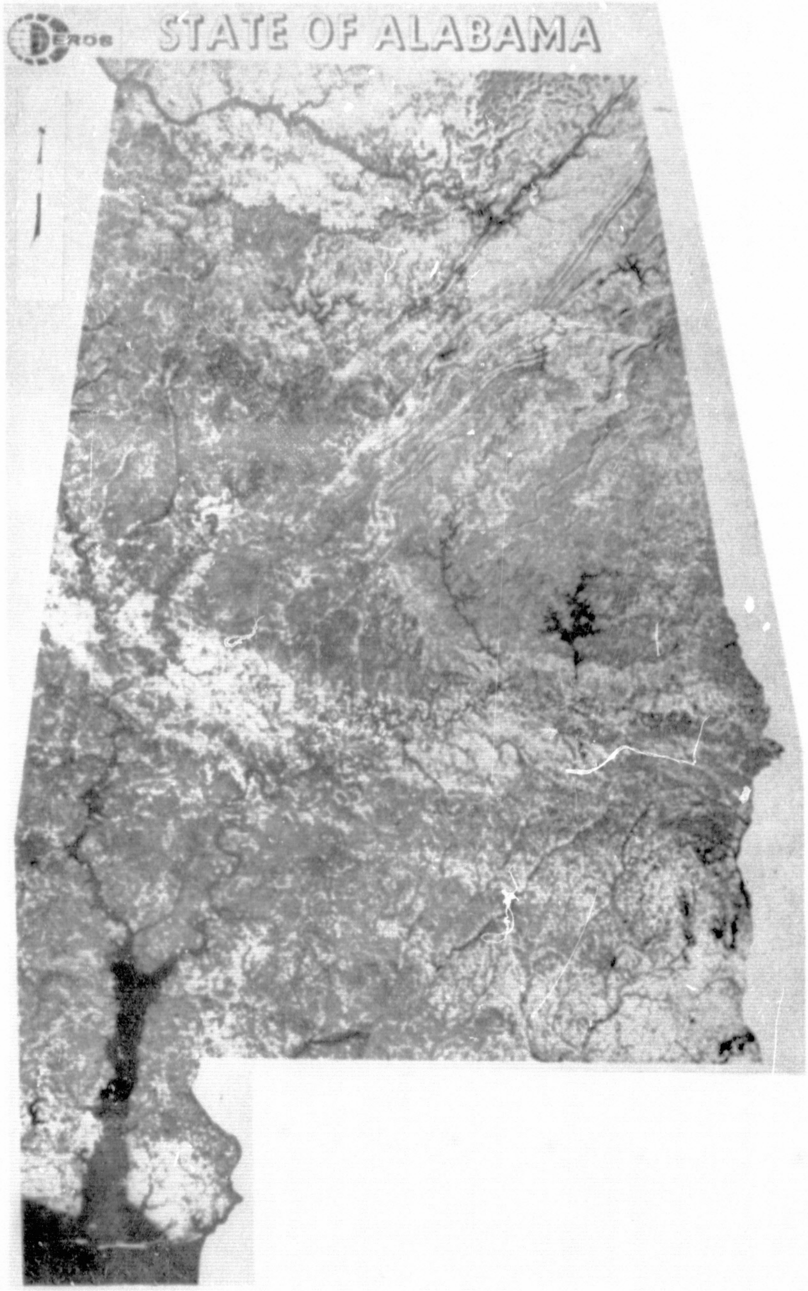

WATER RESOURCES PLANNING
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ABSTRACT

ABSTRACT

There is a growing awareness that the natural resources of the world are limited. This fact gives credence and a sense of immediacy to those who are trying to better understand and describe those processes which affect the amount and the quality of these resources. One of the most abundant and most taken-for-granted natural gifts is water. The waters adjacent to coastal regions are some of the most often studied because of their importance to man.

The coastal environment is a vital part of man's daily activity - providing food, recreation, jobs and habitats. Thus the already complex, dynamic natural processes which maintain a balance between fresh water and saline water is further confounded by man-made impacts. To minimize adverse events on these areas, a clear understanding of the properties and behavior of these systems must be established. Plans formulated with technically sound data are far more likely to produce results which are both environmentally and economically sound.

In recent years, studies have been accelerated to better characterize the coastal waters and to better describe the processes which take place in these areas. Studies have included models - both mathematical and physical - as well as the more traditional investigations involving data acquisition - both field oriented and remotely sensed. The interaction of these methods provide techniques for the rapid prediction of changes in the system and the impact that these changes have on water quality and behavior.

The National Aeronautics and Space Administration, Marshall Space Flight Center (MSFC) has had a continuing interest, through their Environmental Applications Branch, in the application of remote sensing, automatic data processing, modeling and other aerospace related technologies to hydrological engineering and water resource management. One such investigation includes major hydrological and water resource emphasis for the entire river drainage system which feeds the Mobile Bay estuary. This study has a particularly significant and timely purpose as a result of the development of the Tennessee-Tombigbee Canal, a project which will connect the Tennessee-Ohio River systems to Mobile Bay via the Alabama-Tombigbee Rivers. The impacts created by this construction and other such developments on the water quality and hydrological characteristics of the bay are of primary concern and importance.

As part of that study, MSFC has funded projects under contract NAS8-29100 to investigate the adaptation and implementation of existing mathematical modeling methods for the purpose of describing the behavior of Mobile Bay. Of particular importance are the interactions that system variables such as river flow rate, wind direction and speed, and tidal state have on the water movement and quality within the bay system.

Specific achievements of these modeling studies include:

1. The development of a rapid, predictive technique for establishing baseline conditions within the bay system from which other studies can be compared.

2. The determination of the dynamic interchange occurring between the bay and rivers, the bay and the Gulf of Mexico and Mississippi Sound, and the bay with adjacent land masses.

3. The investigation of bay physio-chemical processes and the impact that these have on the water mass. Such items as changes in river flow rates, runoff and pollution loading are assessed in terms of the way they affect distribution and transportation properties within Mobile Bay (currents and tidal elevations).

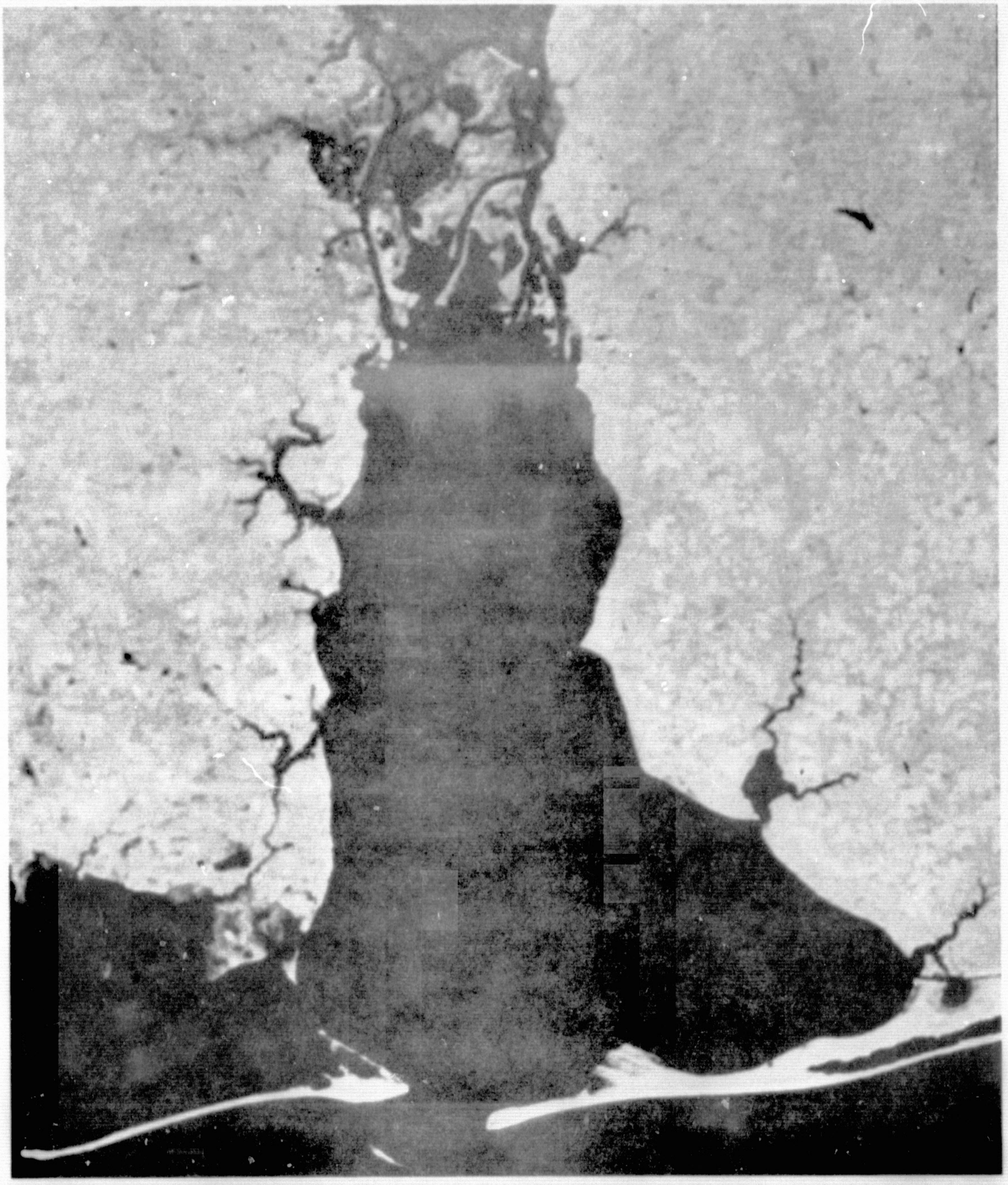
4. The determination of material transport behavior within the water system as controlled by system variables (salinity, sediment transport, coliform bacteria).

5. The establishment of a basic model useful to extend present capabilities to include other material transport problems (BOD/DO distributions, oil spill transport).

6. The development of a method to interface the bay model with selected subsystems designed to provide a closeup view of certain local disturbances (dredge discharge material transport, Little Dauphin Bay model).

7. The establishment of a method with the capability of interacting with field oriented, data processing and remote sensing programs which are concurrent with contract NAS8-29100.

These achievements and the programs which are suggested for further investigation are the subject of this final report. The work presented represents nearly three and one half years of investigation at The University of Alabama under the support of contract NAS8-29100 with the Marshall Space Flight Center of the National Aeronautics and Space Administration.



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CONTRACT PLANS

CONTRACT PLANS

The primary objective of contract NAS8-29100 was the demonstration of the utility of mathematical modeling methods in

1. the rapid, predictive analysis of behavior occurring in a complex system such as Mobile Bay,

2. the development of a strong data base from which the impact of future events on bay quality and movement could be compared, and,

3. the establishment of a technique to complement remote sensing and automatic data processing methods.

To achieve these objectives, various tasks were established throughout the course of the study, each building on the experience and knowledge gained from the previously completed elements. Each of these tasks, their status and their contribution to achieve the contract objective are listed in Table 1.

In subsequent sections of the report, detailed results derived from the modeling studies (listed in Table 1) will be presented to illustrate the range, depth and utility of the methods. Prior to that, however, a brief description of the Mobile Bay system, a summary of the model equations, and the sources of available data used to implement the models are needed to place the results of the investigations into a familiar setting for discussion and review.

Table 1. -Contract Plan by Work Element Showing Current Status and Past Reports Issued.

Work Element	Comments	Reports Issued
I. Review of Existing Mathematical Models for Estuarine Systems	I. Completed under Marine Science Programs Project.	
II. Adaptation of Models to Mobile Bay System A. Hydrodynamic B. Material Transport 1. Conservative (Salinity) 2. Non-conservative (Coliform) 3. Non-conservative (BOD-DO) 4. Conservative (sediment)	II. One third completed under Marine Science Programs Project; two thirds under contract NAS8-29100. II.B.3. Model developed for BOD-DO; insufficient data for verification/calibration.	BER 168-112 BER 169-112 BER 174-112 BER 185-112 BER 208-112
III. Data Acquisition/Identification for Calibration, Verification, Parameter Sensitivity Analyses A. Hydrodynamic B. Salinity C. BOD-DO D. Coliform Bacteria E. Sediment	III.A. Continuing effort due to interaction of hydrodynamic model and material transport models. III.B. Tidal cycle average data only (literature). III.C. Insufficient data. III.D. Monthly average data only (State Department of Health). III.E. Seasonal and longer periods (literature).	BER 168-112 BER 169-112 BER 185-112 BER 208-112
IV. Application of Developed Models to Specific Water Quality and/or Bay System Problems A. River Discharge, Wind, Tidal Conditions (Normal) B. Pollution Loading (Coliform) C. River Discharge, Wind, Tidal Conditions (Abnormal) D. Subsystem Modeling 1. Little Dauphin Bay 2. Bay Dredge Discharge 3. Material Transport Users Manual	IV.A. Abnormal (extreme river flows, storm surges and winds); insufficient data for verification/calibration. IV.D.1. Little Dauphin Bay; insufficient data for verification/calibration. IV.D.2. Maintenance Dredging activities; Corps of Engineers data. IV.D.3. Incorporated to increase users participation (replaced elements III.C. and IV.C.).	BER 168-112 BER 169-112 BER 185-112 BER 203-112 BER 208-112 BER 203-112
V. Technology Transfer A. Reports B. Manuals C. Workshops, Conferences D. Papers, Presentations	V.A. Interim reports (fourth quarter 1976 includes a final report).	BER 209-112 (Final)

WATER RESOURCES PLANNING
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THE MOBILE BAY SYSTEM

THE MOBILE BAY SYSTEM

Mobile Bay is approximately 400 square miles in area and is located on the northeastern shoreline of the Gulf of Mexico east of the Mississippi River delta. The estuary is about 31 miles long and varies in width from 8 to 10 miles in the northern half to about 24 miles wide in the southern portion (Figure 1). The southeastern region of the estuary is referred to as Bon Secour Bay. The southern end is blocked from the open Gulf by land barriers; Gulf Shores to the east and Dauphin Island to the west. There are two passes located in this area also; the main pass which connects with the Gulf at Mobile Point and the pass which connects with Mississippi Sound at Cedar Point.

The bay is the terminus of the Mobile River system which consists of more than 43,000 square miles of drainage basin; the fourth largest in the United States. Variations in river discharge rate from a ten year average high of 136,000 cubic feet per second in March to a ten year average low of 16,000 cubic feet per second in September have been recorded. During periods of heavy runoff the bay receiving waters are dominated by the high river flows to the extent that salinity intrusion within the bay is suppressed to the mid and lower reaches of the estuary. Conversely, during low flow periods, salinity concentrations of 15 to 20 ppt are measured in the upper bay.

Also, as a result of the large region drained and the relatively high river flows during the rainy season, suspended sediment loads equivalent to about 5.5×10^6 tons/yr are carried to the bay. Estimates show that approximately two-thirds of the load is deposited within the bay resulting in long term bathymetric modifications controlled by the hydrodynamic and material transport properties of the estuary. The variation in sediment load observed during the period 1952-1963 is from a high of 1.0×10^6 tons for the month of March to a low of 5.5×10^4 tons for the month of August (1).

Shoaling in the bay has averaged about 2 feet per century. However, there are portions of the bay which are highly stable and other regions which have rates of nearly 10 feet per century. These wide variations are a result of the complex, natural circulation patterns and man-made influences such as channel construction and maintenance dredging activities which exist in the bay. Nearly 1.8×10^6 tons of suspended sediment bypass the bay annually. This material discharges into the Gulf through the two natural passes in the southwestern area of the estuary. During tidal dominant periods (especially during flood tide cycles) solids can be introduced into the bay from the Gulf. These materials are transported to the bay mouth by the predominantly east to west littoral current which occurs in the northeastern Gulf of Mexico. In addition to the riverine and tidal influences on circulation and material transport in the bay, wind direction and speed is also an important variable (2).

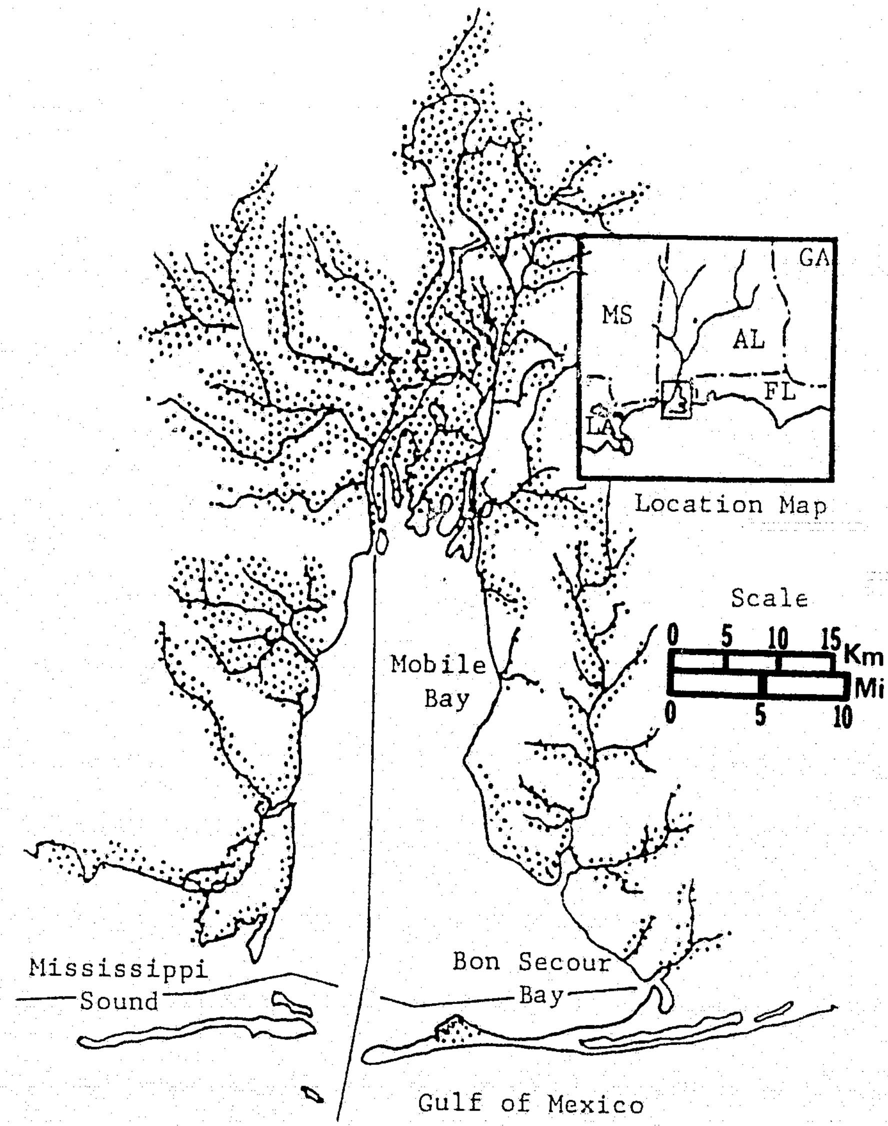

Figure 1. Mobile Bay Estuarine System.

Sewage, industrial waste disposals, and storm water overflow discharged into Mobile River and surrounding creeks from the Mobile metropolitan area, and excessive concentrations of bacteria in the Mobile River, result in the pollution of Mobile Bay. One method for expressing the bacterial content of these waters is to determine the total coliform bacteria group count which gives an indication of the disease carrying bacteria or pathogenic content in the water. Because of this pollution, Alabama, under state laws and the regulations of the State Board of Health, periodically closes the bay to oyster harvesting as a safeguard to human health.

Rapid predictive methods supplemented with spot analytical support could result in substantial savings of time and effort in analyzing bay behavior in the above categories. The method could also provide answers related to the abatement and prevention of serious upsets to the system. This study provides such a method which has a basis the application of conservation of mass and species equations subject to the bay ecosystem constraints. For this purpose, a two dimensional (surface), non-conservative species transport model is developed for Mobile Bay. The model is solved with a finite difference method and implemented by computer solution using a UNIVAC 1110 system. The hydrodynamic model for Mobile Bay developed by Hill and April (3) is used to provide basic current and dispersion coefficient data required by the non-conservative species transport model (NCSTM) and the conservative species transport model (CSTM). Calibration and verification of the CSTM for salinity and sediment distributions, and the NCSTM for coliform bacteria were achieved using available field data for each species investigated.

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MATHEMATICAL MODELS
OF THE MOBILE BAY SYSTEM

MATHEMATICAL MODELS OF THE MOBILE BAY SYSTEM

The equations which make up the mathematical modeling package for Mobile Bay are shown in Table 2. Modifications at the boundaries of the system, including river-marsh interaction, and stratification (salt wedge) effects, have been incorporated into the solution method. Similarly, coliform die-off rate constants and sediment resuspension and settling rates are introduced when these elements are studied with the model. The model results are presented as average concentration distributions within the Bay corresponding to the time frame over which field data were available for calibration and verification.

Verification Data Bases For The Mobile Bay Models

Hydrodynamic Model - Synoptic hydrodynamic data at locations within the Mobile Bay system were received from the Corps of Engineers, Mobile, Alabama, for May 15 and 16, 1972. This information consists of tide charts and discharge rates experimentally determined over a thirty-four hour period. Tide heights are taken from the appropriate charts and converted to read from the model reference plane (mean sea level). Fourier series are fit to data by the method of least squares.

Manning coefficients vary from 0.010 to 0.050. A coefficient of 0.050 is used in the marsh area to simulate the low flow rates expected in this zone. Values within the bay proper range from 0.010 to 0.018. Initially, efforts were made to account for variations in roughness created by oyster beds, channels and spoil banks. However, large changes in the Manning coefficient caused only minor changes in the flow on the scale of the model used.

The hydrodynamic model is exercised over four tide cycles beginning with estimates from a previous run. The first step in the verification process is a check of the tidal heights at Mobile State Docks, Great Point Clear, Fowl River, and Bon Secour (Figure 2). Both tidal amplitudes and phases checked closely with the actual data. This is particularly significant in view of the fact that the forcing function in the Gulf of Mexico and at Cedar Point are smoothed data derived from storage equations as previously discussed in relation to boundary conditions. Other factors which may influence somewhat the exactness of the fit are localized winds and adjacent marsh areas that may flood at the high tide.

The second verification step consists of a comparison of discharges at Main Pass and Cedar Point with field measurements taken by the Corps of Engineers (Figure 3). Discharges are calculated by the Corps from periodic measurements at various locations in these passes at a depth of 0.2 and 0.8 times the depth of flow. An arithmetic average of these values is considered to be the average value for that location in the vertical direction. Horizontally, the area covered is half the distance to the adjacent measurement location on either side.

Table 2.--Mathematical Representation and Operational Modes of the Physical Models for Mobile Bay (3,9)

Name	Equation Form	Results	Modes
Continuity	$\frac{\partial Q_x}{\partial x} + \frac{\partial Q_y}{\partial y} + \frac{\partial H}{\partial t} = -(R + E)$	Tidal Height	Tidal Cycle Daily Avg Monthly Avg Seasonal
Momentum x-Component	$\frac{\partial Q_x}{\partial t} + gD\frac{\partial H}{\partial x} = KV^2\cos\psi - fQQ_xD^{-2}$ $+ Q_x(2W\sin\varphi)$	x-Component of Surface Current	Tidal Cycle Daily Avg Monthly Avg Seasonal
y-Component	$\frac{\partial Q_y}{\partial t} + gD\frac{\partial H}{\partial y} = KV^2\sin\psi - fQQ_yD^{-2}$ $+ Q_y(2W\sin\varphi)$	y-Component of Surface Current	Tidal Cycle Daily Avg Monthly Avg Seasonal
Species Continuity	$\frac{\partial C}{\partial t} + V_x\frac{\partial C}{\partial x} + V_y\frac{\partial C}{\partial y} = E(\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial y^2})$ $+ \frac{E}{D}(\frac{\partial C}{\partial z}(z_s) - \frac{\partial C}{\partial z}(z_b))$ $- \frac{1}{D}(Cv_z(z_s) - Cv_z(z_b))$ $+ R_o$	Concentration of Species	
Salinity	$R_o = 0$	Salinity Concentration	Daily Avg Seasonal
Coliform	$R_o = KC$; where $K = f(\theta)$	Coliform Bacteria Concentration	Monthly Avg Seasonal
Sediment	$R_o = K_1f(v_s) + K_2f(E) - K_3f(v_r)$	Suspended Sediment Concentration	Seasonal Tidal Cycle

Note: f in the above equations denotes a functional representation of the variable listed in parentheses.

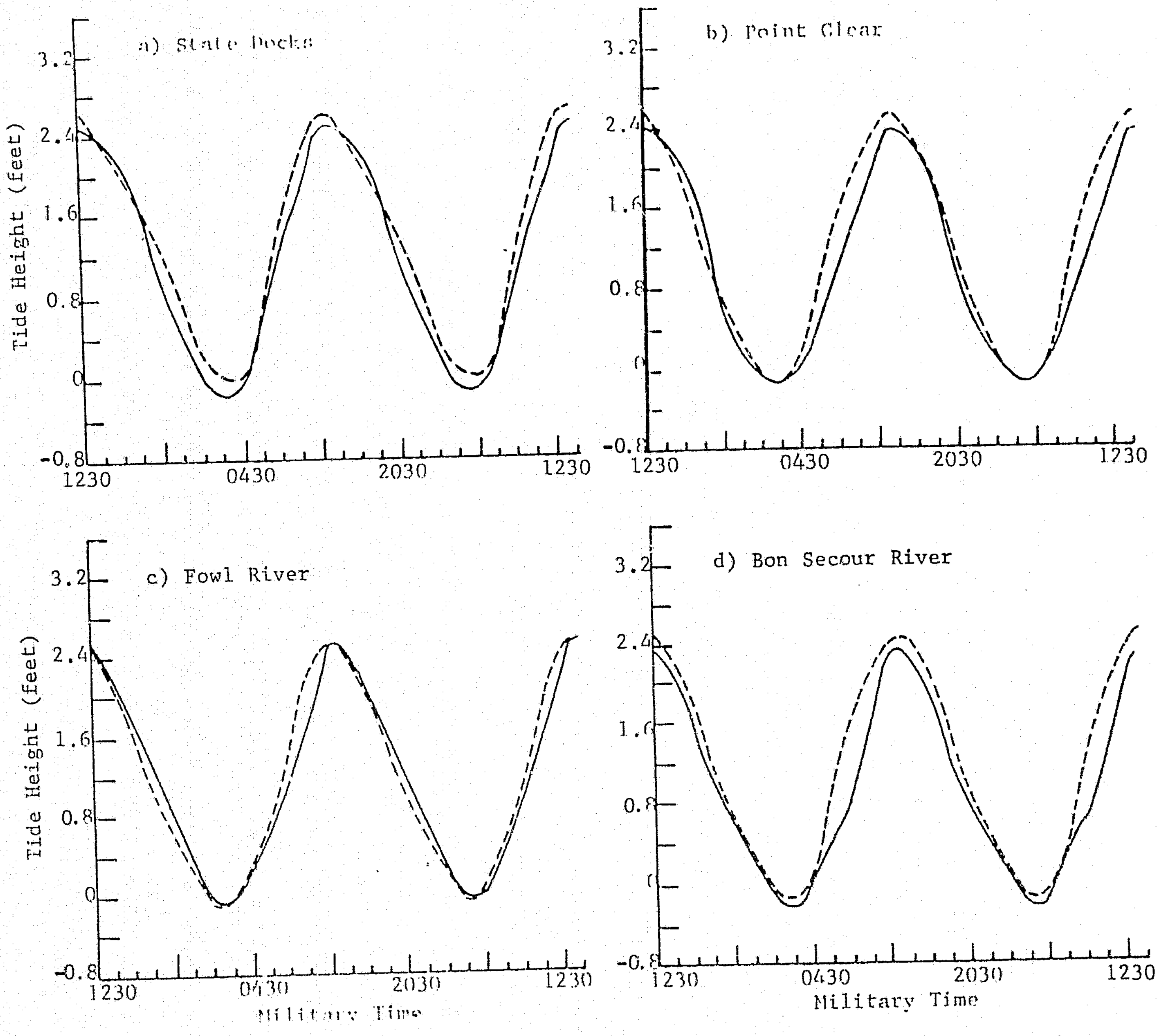


Figure 2. Tidal Cycle at Four Locations in Mobile Bay for Model (Dashed Line) and Field (Solid Line) Results.

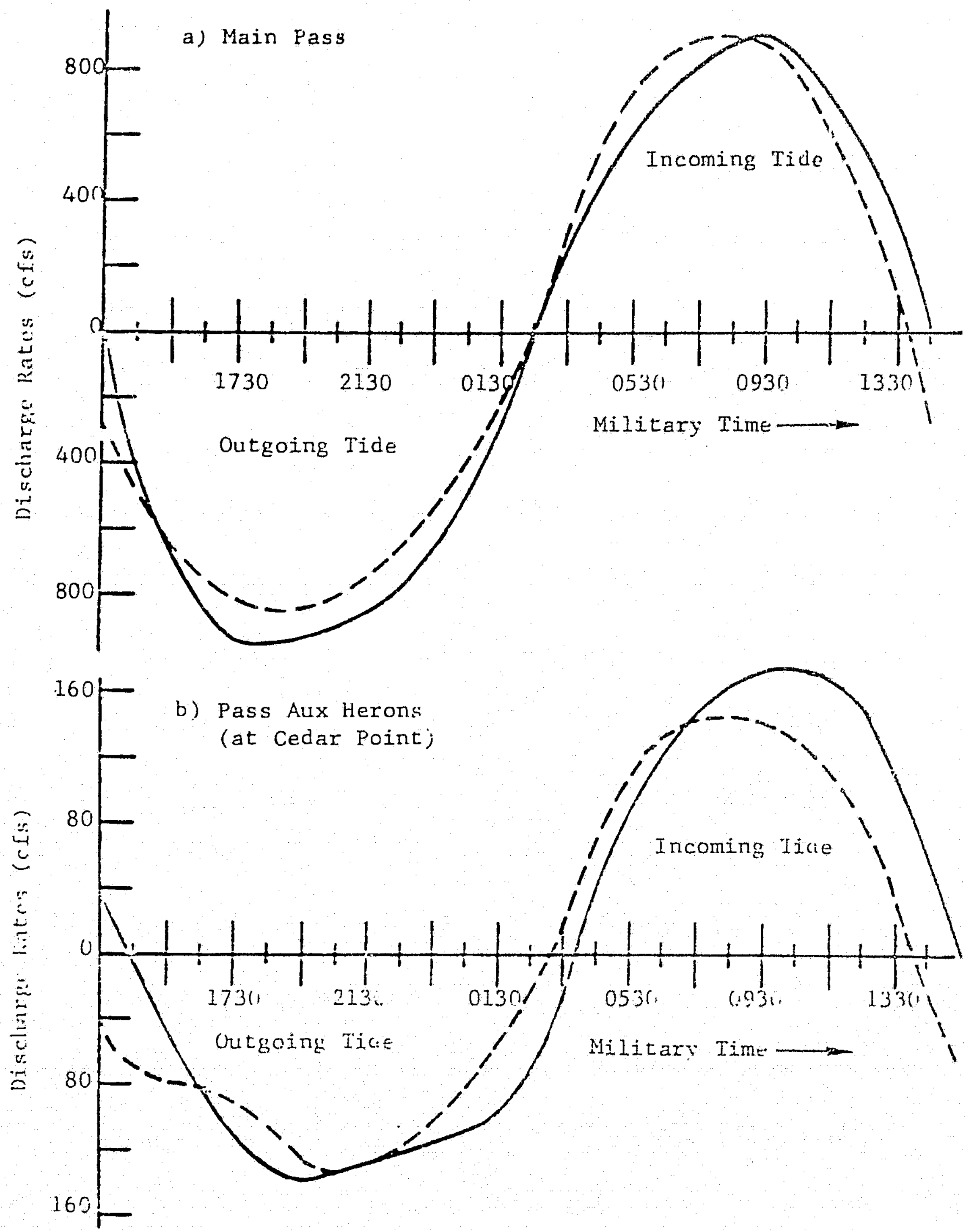


Figure 3. Discharge Rates at Two Locations in Mobile Bay for Model (Dashed Line) and Field (Solid Line) Results.

The correlation between actual data and model predicted data at Main Pass is excellent. This was expected since flows through this pass are well behaved and influenced little by the flow at Cedar Point. There is a slight deviation at Cedar Point between model predicted values and field data. During the course of this study, it became evident that flows through Main Pass have a direct influence on the flows through Cedar Point (4).

A final step in the verification process is qualitative in nature and involves a visual comparison of flow patterns predicted by the model with those postulated from field observations (5). Comparative inflow (flood) and outflow (ebb) profiles are shown in Figure 4. The trend of water movement predicted by the model is in agreement with the literature data. Water entering through the Main Pass on the flood tide sweeps through Bon Secour Bay then turns to a northerly direction and flows toward the Blakely and Apalachee Rivers. During ebb flow, the water movement is from the upper bay and Bon Secour Bay toward the Main Pass. The patterns illustrated using literature data are derived from data collected over different periods of time. Therefore, they are only used here to indicate a trend in surface water movement for comparison with the depth averaged model results.

Salinity Model - Considerable salt concentration data were found in the literature for the month of October, 1952. Average river flows obtained from the United States Geological Survey for this time period indicated a fresh water input of 12,000 cubic feet per second. The hydrodynamic model was exercised using the modified river flows to compute the pertinent data for the salinity model.

Dispersion coefficients and net velocities, calculated in the hydrodynamic model for each grid location, were used as input data for the salinity model. The Gulf boundary saline concentration was set at thirty-five parts per thousand. The concentration at Cedar Point for October, 1952, was elucidated from the literature (3) and set at twenty-five parts per thousand. Dog River and Mobile River were set at zero concentrations.

The salinity wedge was accounted for in the Bon Secour area. This area was chosen rather than the ship channel for several reasons. First of all, data available indicates that the effects in the ship channel are minimal which may be due to the low comparative surface area involved on the scale of the model studied. Secondly, the literature (5) indicates that a large area in Bon Secour is influenced by the wedge. This is expected as a result of the flow patterns in the area. Finally, the model indicates that the salinity wedge in Bon Secour significantly contributes to the overall salinity patterns. This was achieved in the model using a first order equation for the rate of mass transfer from the salt wedge to upper water layers. Simulating the three dimensional salt wedge effect in this manner gave model results in closer agreement with reported field data (Figure 5).

The salinity mdoel was exercised for thirty-two tide cycles beginning with estimates from a previous run. Data from the

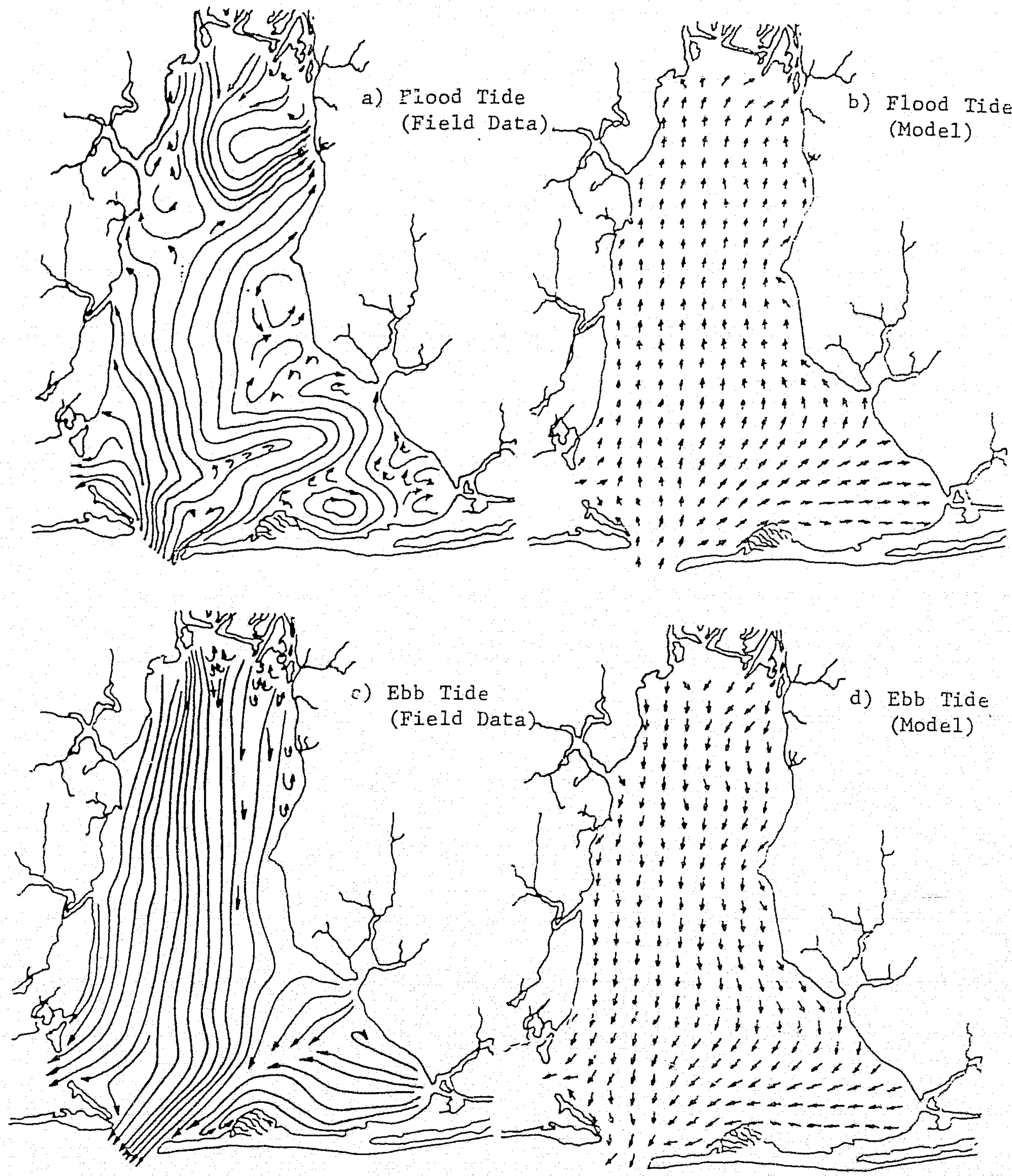


Figure 4. Velocity Patterns for Ebb and Flood Tide Conditions in Mobile Bay.

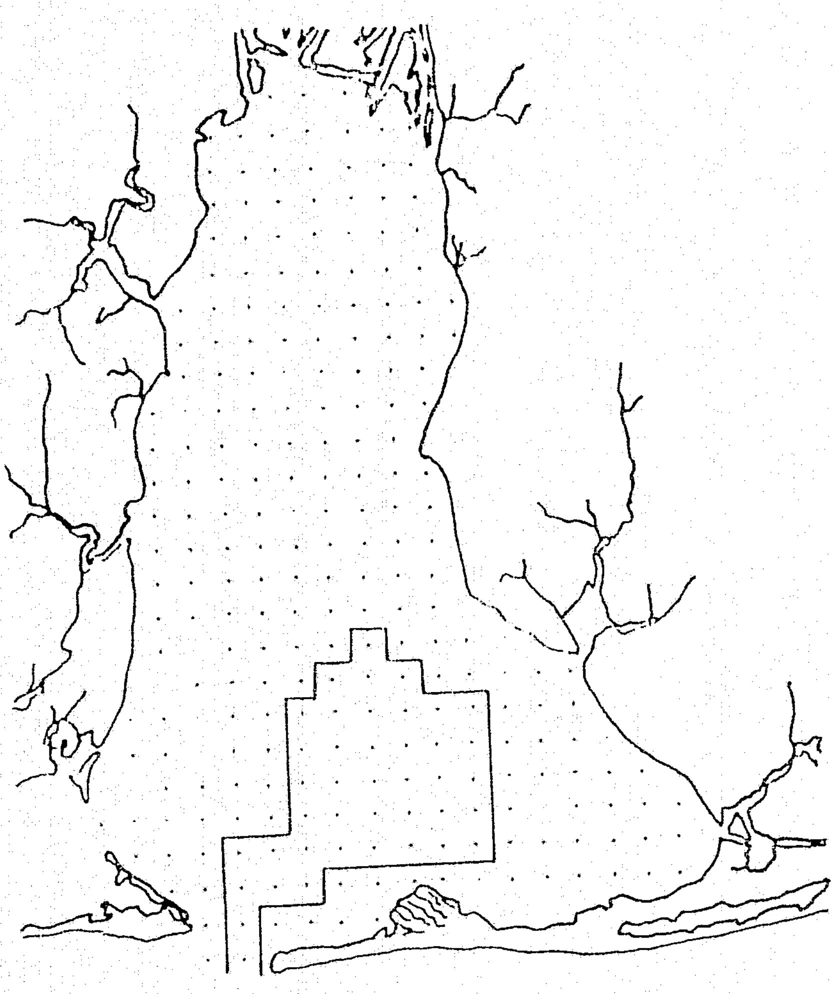


Figure 5a. Area in Bon Secour Bay Observed to be Affected by Stratification (Salt Wedge).

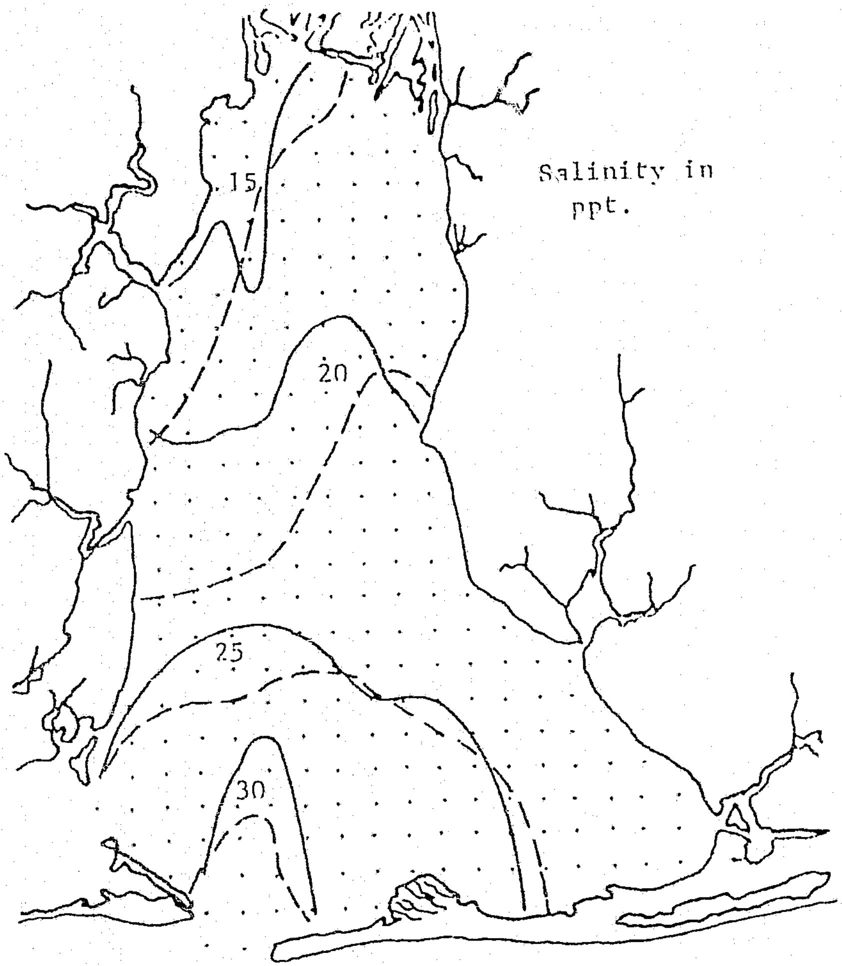


Figure 5b. Salinity Distribution Curves in Mobile Bay for Model (Solid Line) and Field (Dashed Line) Data.

literature (5) were averaged for ebb and flood tides as well as in the vertical direction and compared with model trends. Results are in general agreement with the field data (Figure 5). A deviation along the western side of the bay may be the result of unidentified fresh water flows in this area, as was Dog River at the outset of this study. This is surmised from several pieces of information. Data from the literature indicate a rather strong net outflow along the extreme western shore even for low fresh water flows (5). This is in contrast to Earth Resources Technological Satellite photography and coliform profiles which indicate the main thrust of net outflow is down the ship channel and minimum flows adjacent to the western land boundary (6). Even with the possibility of additional fresh water flows, the model-predicted isohalines appear reasonable and lead to a study of natural phenomena expected in Mobile Bay as a function of various wind and river conditions.

Coliform Bacteria Model - Total coliform group concentration data for various locations in Mobile Bay were collected by the Alabama State Department of Health for the period from January 1962 to August 1962. Coliform group concentrations are obtained by analysis as described in the outline entitled "The Significance of EC Positive Organisms in Gulf Shellfish Growing Waters" (7).

The model is verified on a monthly basis, i.e. monthly average conditions are used,and the model results are tabulated and compared to the monthly average values of actual data. The criterion for model verification is based on how well model-predicted results fall within the field data range at the several locations within the bay for any given monthly period.

Because of the dependence of the species continuity equation on the hydrodynamic model of Mobile Bay for current distributions and dispersion coefficients, the first step in the verification procedure involves specification of data necessary for the proper description of the hydrodynamic behavior of the Bay. This includes the calculation of monthly average river flow rates, wind conditions and tidal conditions for the period for which total coliform group concentration data are available (Table 3).

Additionally, the total coliform dieoff rate constant K_r used in the model is calculated as a function of monthly average water temperature of the bay (Table 4). These temperatures are estimated from the bimonthly average water temperatures of Mobile Bay compiled by Bault (8). It is recognized that water temperatures are not uniform in the bay. The degree of mixing that occurs between sea water and river water within the bay will affect the temperature distribution. In this study temperatures are considered homogeneous throughout the bay. Temperatures can be adjusted linearly between the values corresponding to Gulf of Mexico water temperature and river water temperature to approximate real system behavior. In this study where monthly average values are investigated the sea water intrusion effect can be neglected.

Table 3. River Discharge Rates for the Period January to August, 1962 in cfs.

Month	Mobile River	Dog River	Tensaw River
January	130,000	5,000	73,800
February	100,000	3,000	51,700
March	90,000	2,500	53,100
April	130,000	4,000	56,900
May	20,000	2,000	18,500
June	15,400	1,500	10,000
July	10,000	1,000	9,200
August	8,000	500	4,500

Table 4. Temperatures, Dieoff Rate Constants, and Wind Conditions for the Period January to August, 1962.

Month	Temperature	Dieoff Rate Constant K_r	Wind Conditions		
			Speed	Direction	
	^oF	day^{-1}	knots	from	θ deg.
January	49.5	0.26	12.3	N	90.0
February	53.2	0.29	12.0	S	270.0
March	61.3	0.39	12.6	N	90.0
April	67.9	0.50	10.7	SSE	292.5
May	78.1	0.72	7.9	SW	225.5
June	81.4	0.81	5.7	NE	45.0
July	83.7	0.88	5.9	SW	225.5
August	84.2	0.90	5.2	ENE	22.5

Total coliform group concentration data for locations recognized as having severe pollutant input into the bay are used as loading concentrations at each relevant grid cell (Table 5). They are held constant throughout each computation. Loading at the Mobile River has been found to be the main source of pollution of Mobile Bay (9).

Results are presented as model calculated total coliform profiles within Mobile Bay (Figure 6 to Figure 13). Similar results are tabulated for each month from January to August, 1962, during which the verification phase is performed (Table 6 to Table 13). Total coliform concentration vs. time (month) curves for the bay locations indicated in Figure 14 are also presented to show the trend in the concentration changes with season (Figure 15 to Figure 27). Details of the calibration and verification methods used can be found in reference (9).

Sediment Model - Mobile Bay experiences seasonal variations in rainfall, runoff and sediment loading which can be broadly classified as low, medium and high in a manner outlined in Table 14.

During the heavy runoff period (high) the bay receiving waters are dominated by the high river flows to the extent that salinity intrusion within the bay is suppressed to the mid and lower reaches of the estuary. This condition also causes the most severe material transport and deposition of sediment within the bay system. Conversely, during periods of reduced river flow and sediment loading, bay currents are dominated by the tidal influence. This results in a greater potential to transport sediment although the total volume is significantly reduced because of the low runoff conditions.

The data used for this study are seasonal average river flow and sediment loads obtained from the literature for the period 1952-1963. This information is used in the hydrodynamic model to calculate a tidal cycle average velocity which is then related to sediment transport potential by correlation with a critical velocity. Using this information, trend analyses of Mobile Bay sediment deposition reported as a potential function are included. These results include seasonal and longer variations in the sediment patterns.

Table 5. Loadings of Total Coliform at Various Locations in MPN per 100 ml

Month	Mouth of Mobile River	Mouth of Tensaw River	Mouth of Dog River	Alabama Port	Cedar Point	Mouth of Bon Secour River
January	20,500	2,000	19,000	23,800	2,500	1,500
February	18,125	2,000	13,800	5,000	4,150	1,300
March	99,000	2,000	47,500	2,100	1,100	170
April	54,000	2,000	7,750	2,750	550	120
May	40,000	200	1,800	1,100	200	40
June	700	300	330	15	1	8
July	3,600	1,000	330	60	0	45
August	1,500	200	200	15	2	20

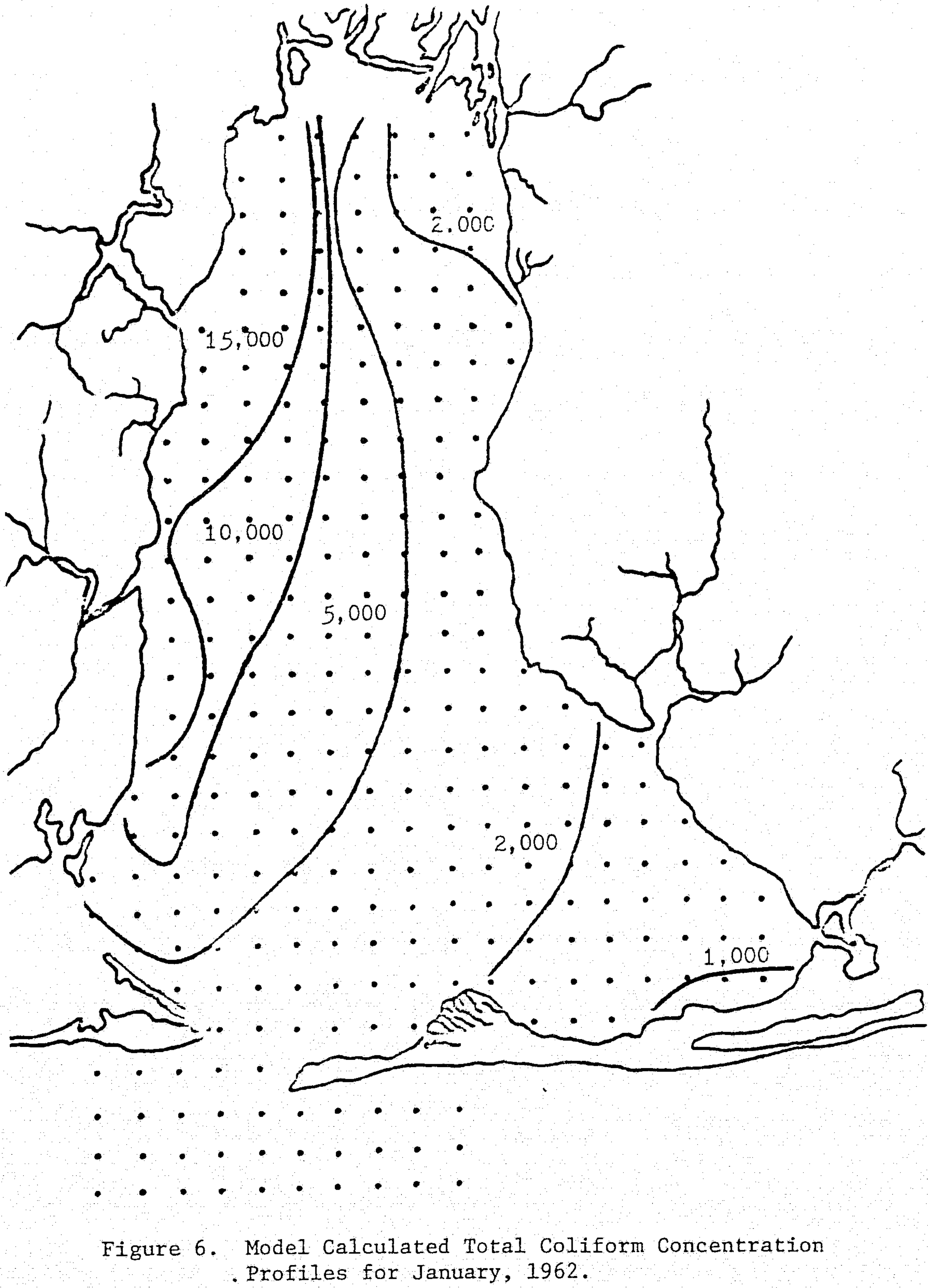


Figure 6. Model Calculated Total Coliform Concentration Profiles for January, 1962.

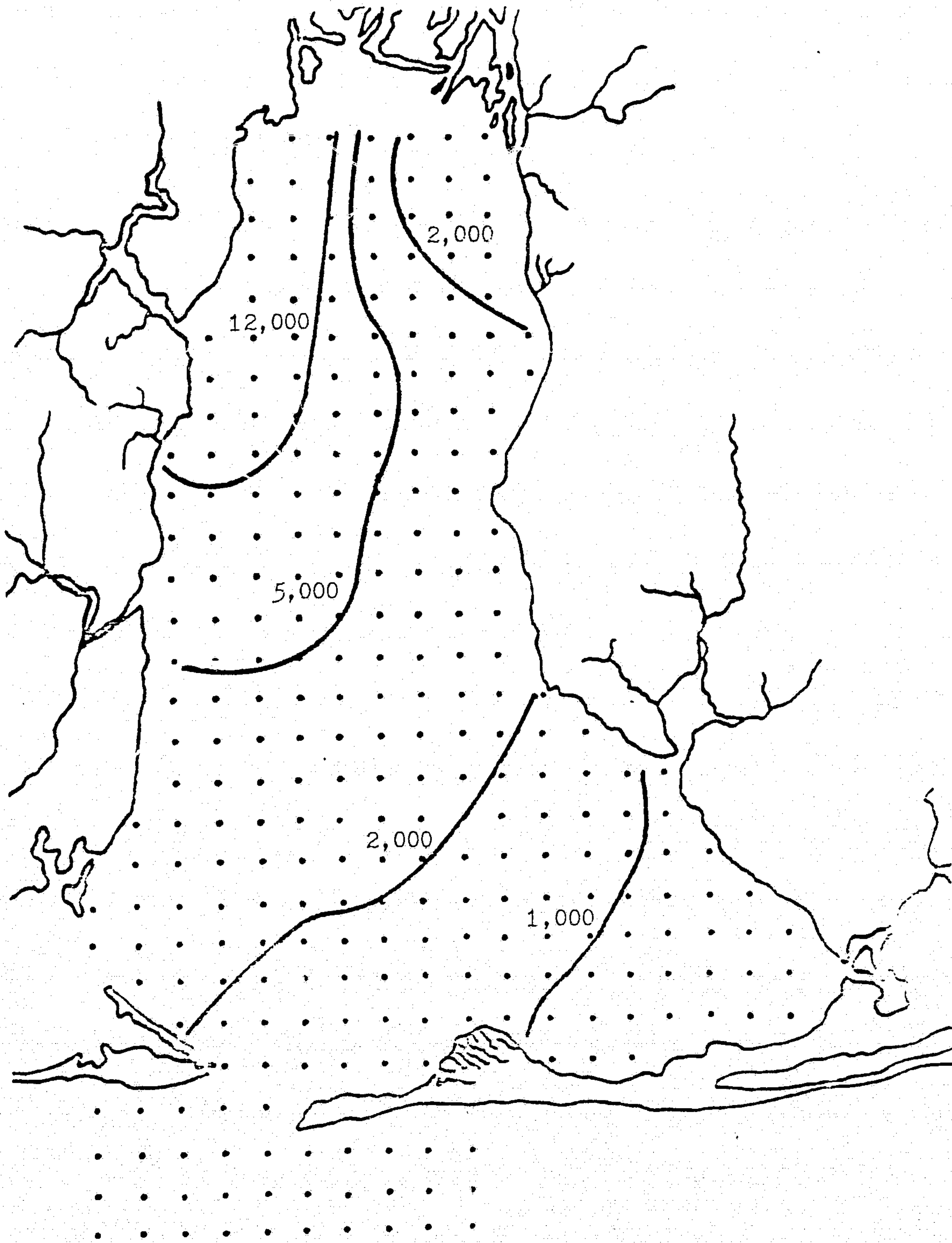


Figure 7. Model Calculated Total Coliform Concentration Profiles for February 1962.

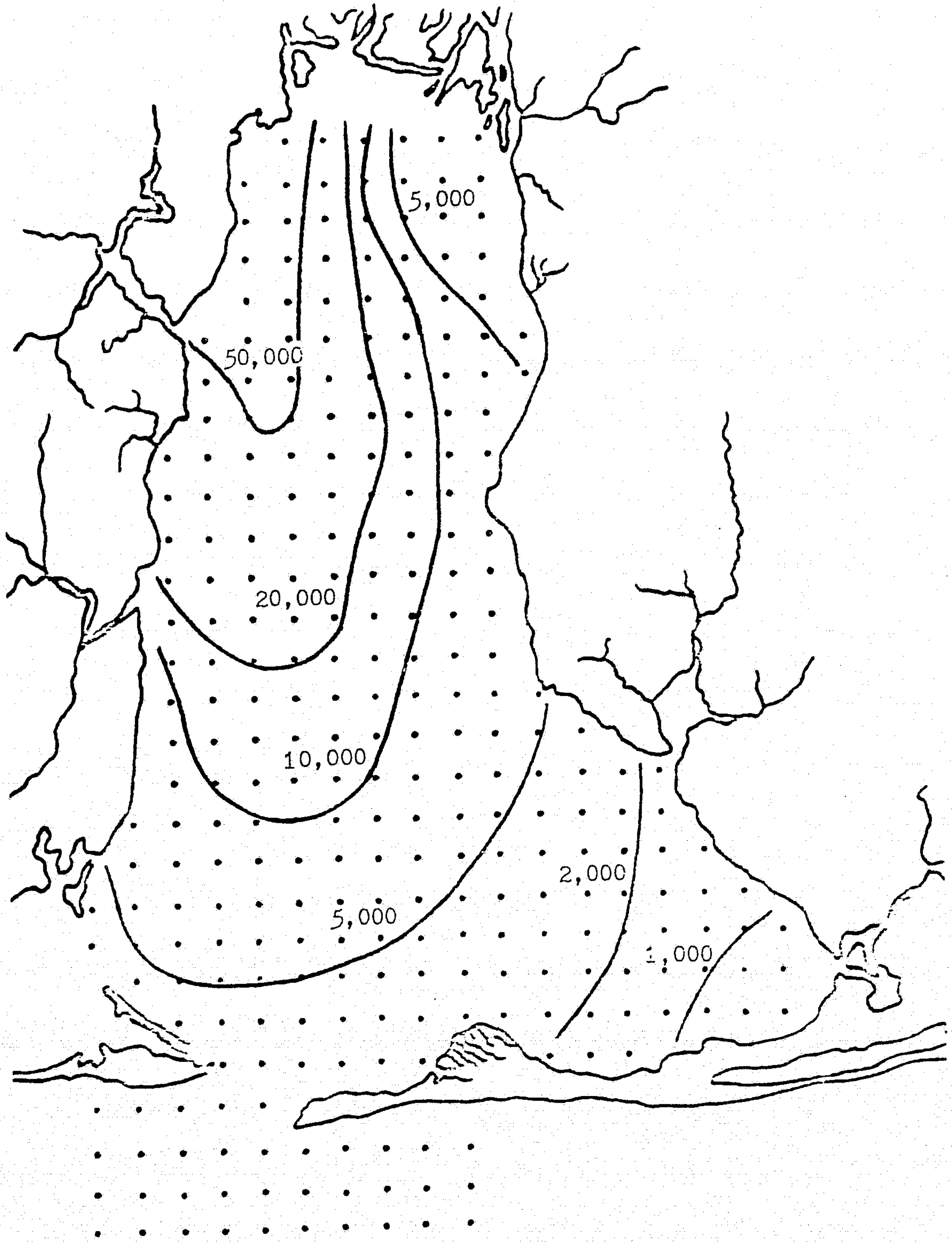


Figure 8. Model Calculated Total Coliform Concentration Profiles for March, 1962.

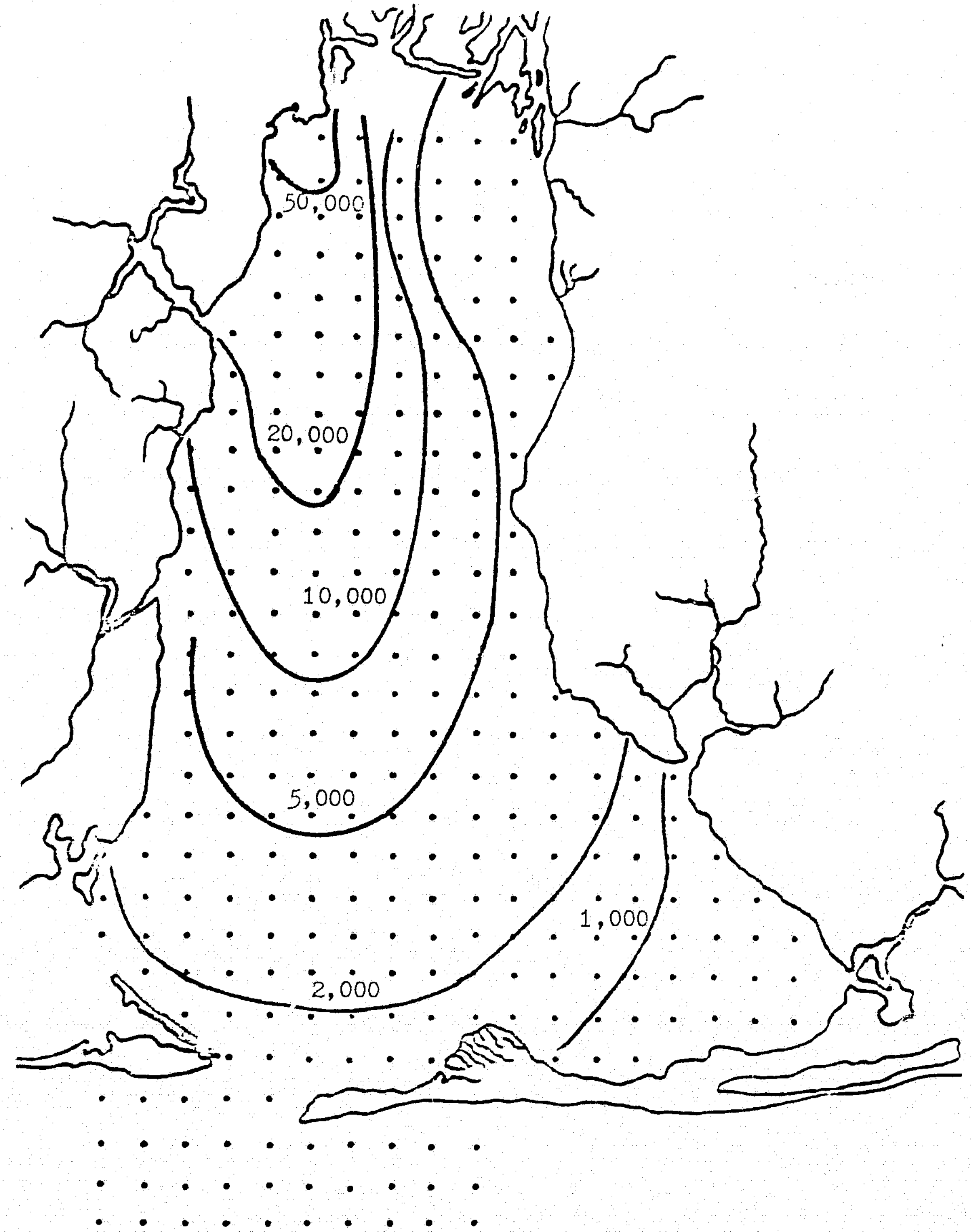


Figure 9. Model Calculated Total Coliform Concentration Profiles for April, 1962.

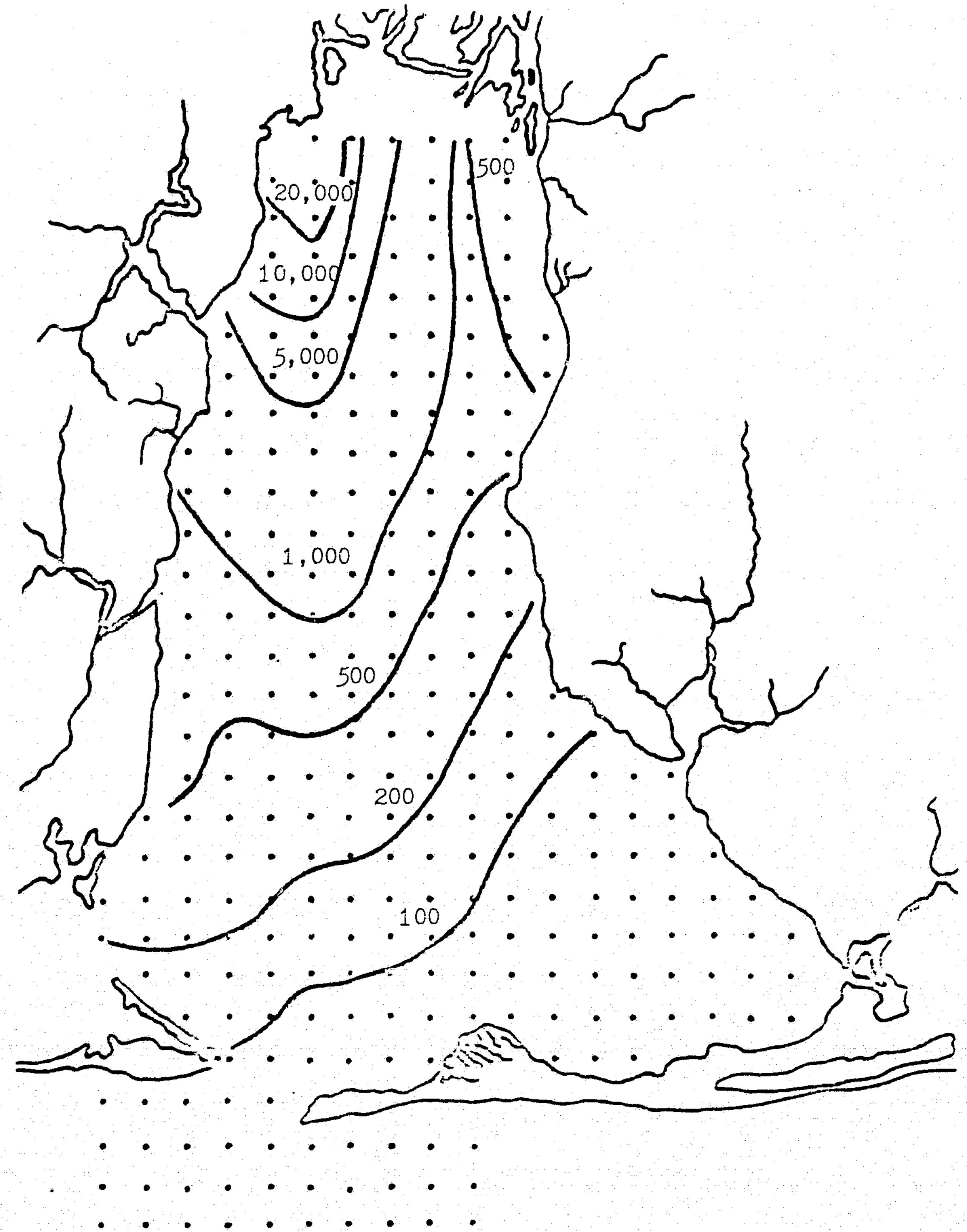


Figure 10. Model Calculated Total Coliform Concentration Profiles for May, 1962.

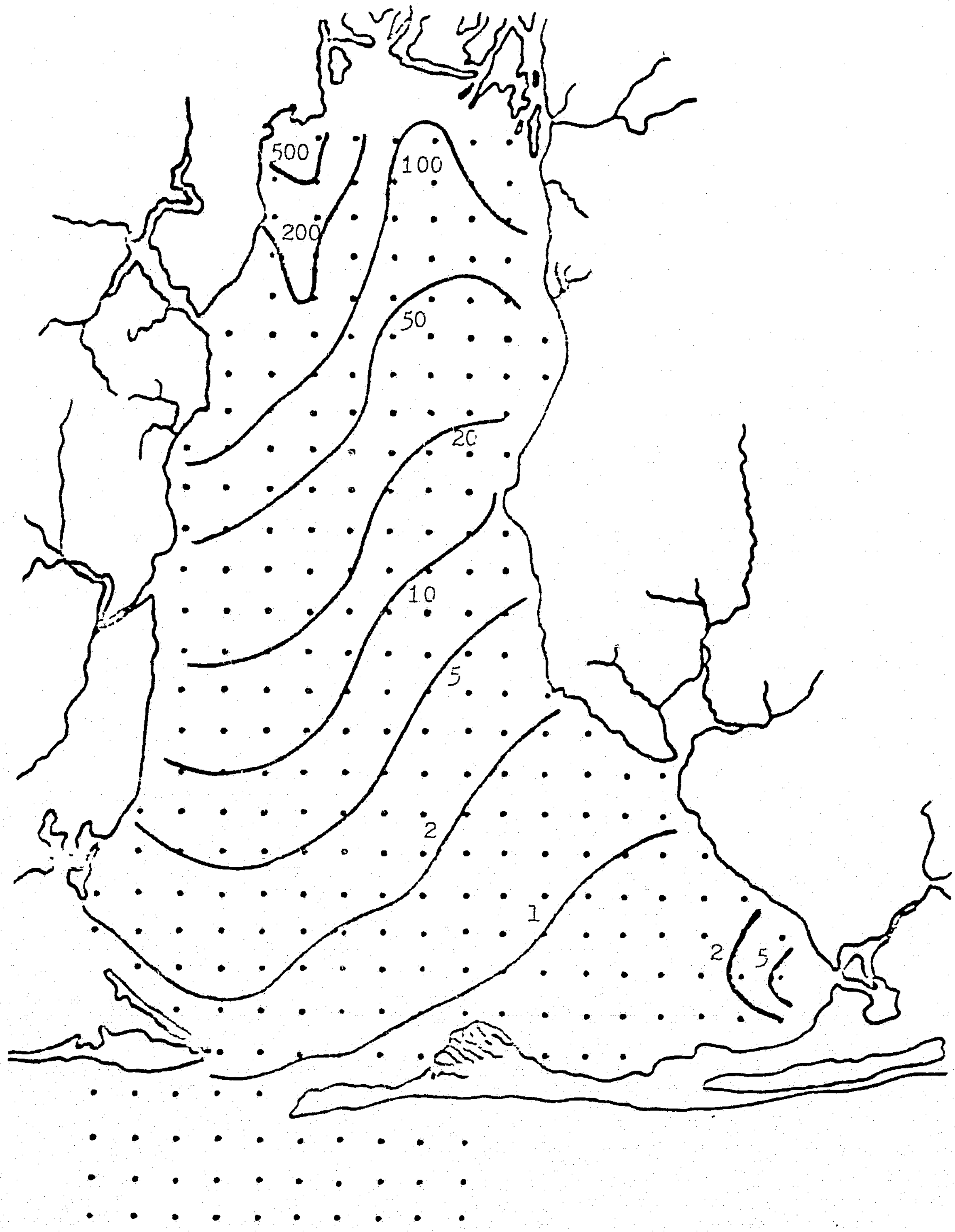


Figure 11. Model Calculated Total Coliform Concentration Profiles for June, 1962.

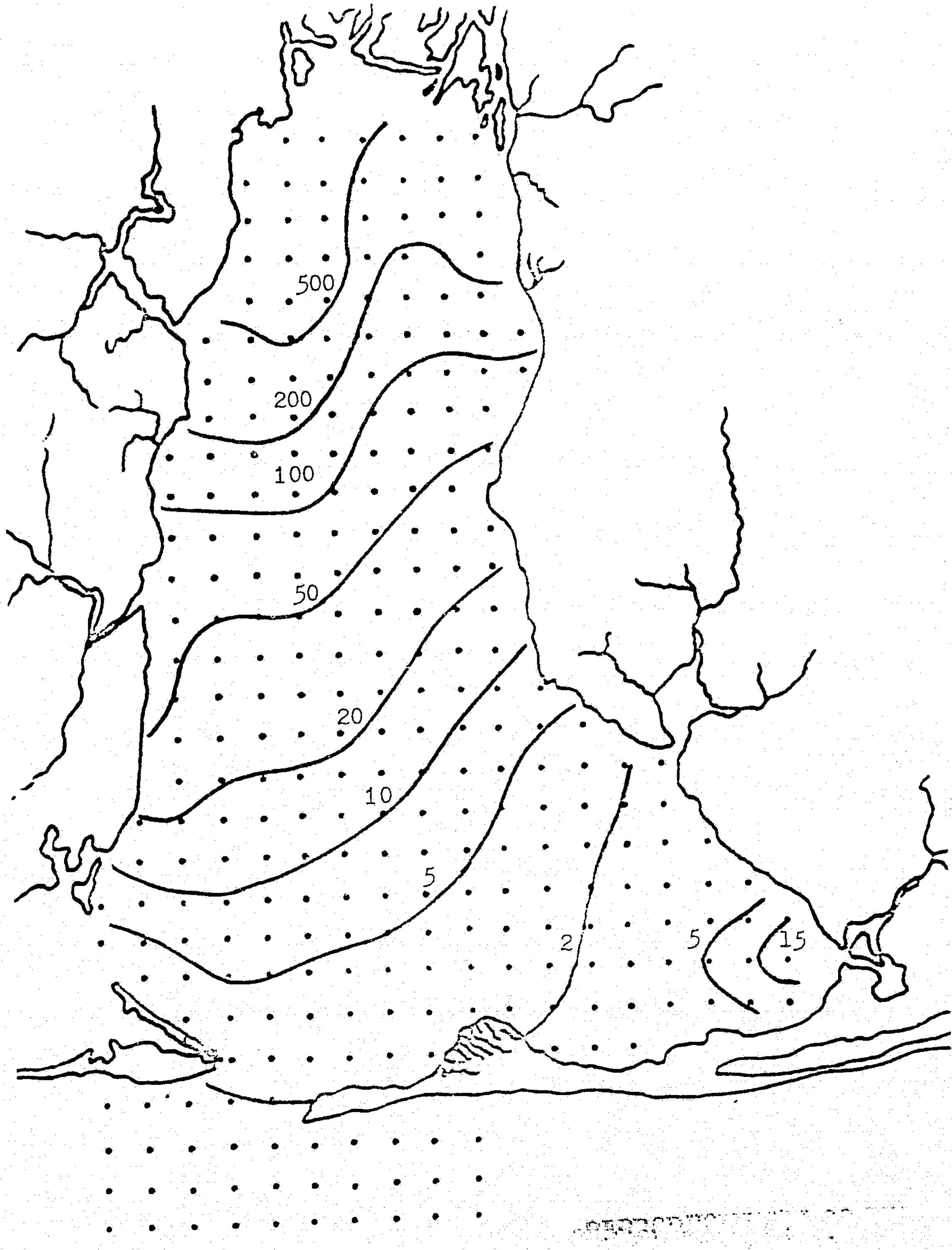


Figure 12. Model Calculated Total Coliform Concentration Profiles for July, 1962.

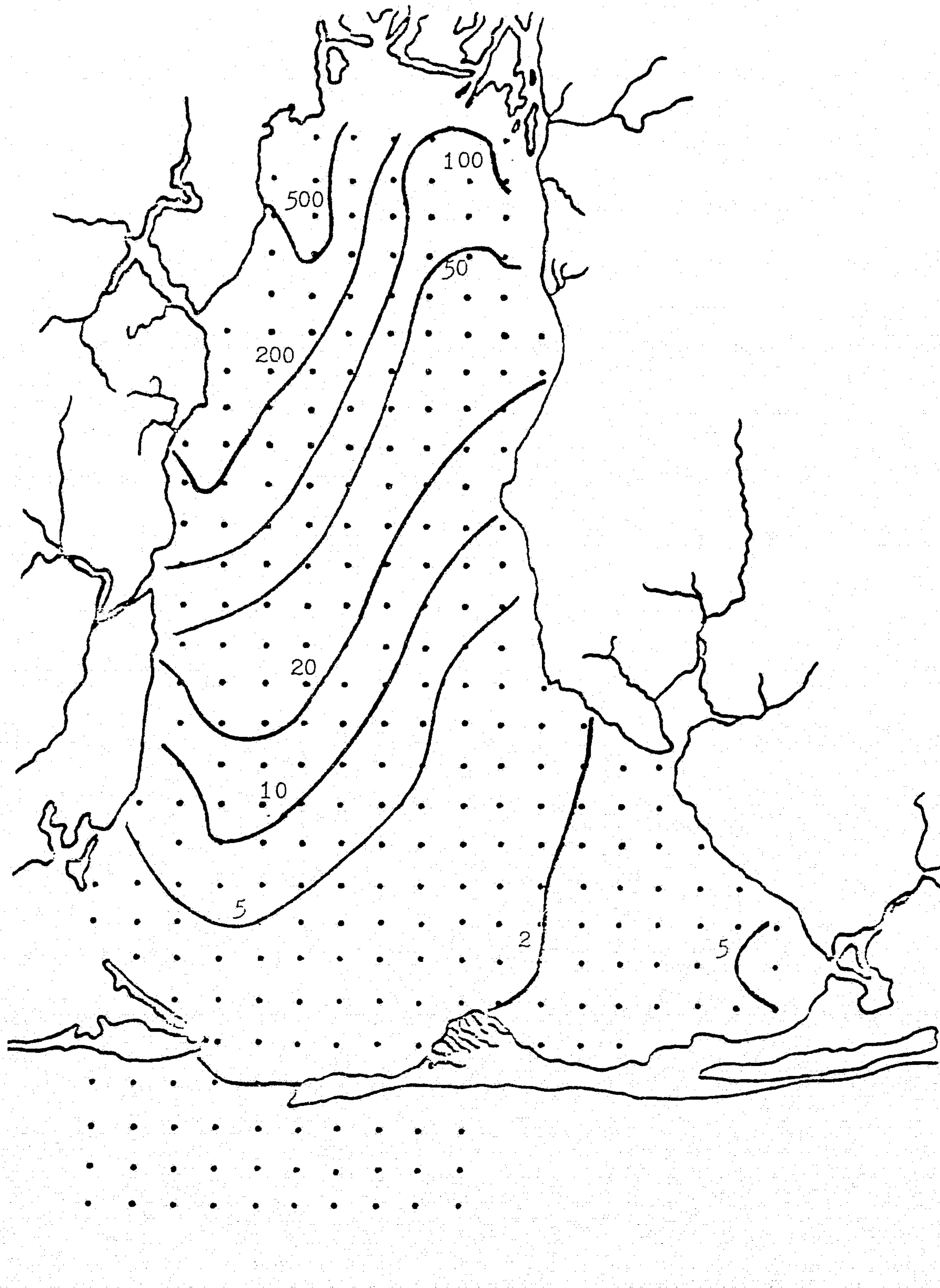


Figure 13. Model Calculated Total Coliform Concentration Profiles for August, 1962.

Table 6. Total Coliform Concentration for Mobile Bay - January 1962
Loading at Mobile River Mouth = 1/4
TC_{31} (D.F. = 4)
Correction Factor for E = 500
$K_r = 0.26 \quad day^{-1}$

Station No.	Measured Data				Model Calculated Result
	No. of Field Sampling	Monthly Average $\bar{x}$	70% Confidence Range		
			$\bar{x} - tS_{\bar{x}}$	$\bar{x} + tS_{\bar{x}}$	
33	4	1,800	1,656	1,944	1,977
36	4	44,500	21,625	67,375	17,958
59	3	5,000	4,206	5,794	6,731
60	3	7,170	5,762	8,578	12,897
61	4	38,000	14,562	61,437	14,235
62	3	24,700	9,496	39,904	15,788
65	2	11,000	-3,157	25,157	4,610
66	4	17,000	10,563	23,435	8,908
67	5	10,400	7,138	13,661	12,360
75	5	7,900	4,175	11,624	9,249
83	3	2,250	1,529	2,970	2,218
88	5	10,100	8,025	12,175	12,422
112	4	530	330	730	1,233

Table 7. Total Coliform Concentration for Mobile Bay - February 1962
Loading at Mobile River Mouth = 1/4
TC_{31} (D.F. = 5)
Correction Factor for E = 500
$K_r = 0.29$ day^{-1}

Station No.	Measured Data				Model Calculated Result
	No. of Field Sampling	Monthly Average $\overline{x}$	70% Confidence Range		
			$\overline{x} - tS_{\overline{x}}$	$\overline{x} + tS_{\overline{x}}$	
33	2	4,500	338	8,662	1,981
36	4	23,000	18,125	27,875	15,415
59	4	5,000	3,312	6,688	5,273
60	4	17,000	10,750	23,250	9,677
61	4	63,500	41,000	86,000	10,548
62	4	27,500	13,750	41,250	10,549
65	4	1,650	881	2,419	3,514
66	4	8,000	7,531	8,468	6,421
67	4	51,500	33,562	69,438	8,407
75	4	15,000	7,312	22,688	5,302
83	3	1,100	300	1,900	1,491
88	4	5,300	1,800	8,800	3,783
112	3	1,380	603	2,156	709

Table 8. Total Coliform Concentration for Mobile Bay - March 1962
Loading at Mobile River Mouth = 1/5
TC_{31} (D. F. = 5)
Correction Factor for E = 500
K_r = 0.39 day^{-1}

Station No.	Measured Data				Model Calculated Result
	No. of Field Sampling	Monthly Average $\overline{x}$	70% Confidence Range		
			$\overline{x} - tS_{\overline{x}}$	$\overline{x} + tS_{\overline{x}}$	
33	2	8,000	4,126	11,874	3,938
36	3	25,000	13,638	36,362	80,734
59	4	160,000	-27,500	347,500	20,108
60	4	69,500	49,688	89,313	41,863
61	4	35,000	15,000	55,000	43,519
62	4	14,000	6,625	21,375	35,070
65	4	4,160	4,060	4,260	11,815
66	4	36,000	11,625	60,375	25,338
67	4	19,250	8,625	29,875	31,766
75	4	15,750	1,763	29,738	17,326
83	4	255	186	324	3,159
88	4	2,800	1,363	4,283	5,375
112	3	55	-3	113	1,089

Table 9. Total Coliform Concentration for Mobile Bay - April 1962
Loading at Mobile River Mouth = 1/4
TC_{31} (D.F. = 4)
Correction Factor for E = 500
K_r = 0.50 day^{-1}

Station No.	Measured Data				Model Calculated Result
	No. of Field Sampling	Monthly Average $\bar{x}$	70% Confidence Range		
			$\bar{x} - tS_{\bar{x}}$	$\bar{x} + tS_{\bar{x}}$	
33	5	1,540	1,008	2,072	2,727
36	5	76,600	44,669	108,531	44,613
59	4	162,000	-50,500	374,500	12,425
60	4	7,250	5,688	8,813	24,451
61	4	27,500	14,313	40,688	23,589
62	4	17,000	7,000	27,000	9,722
65	4	7,100	4,263	9,938	7,201
66	4	8,100	2,725	13,475	15,166
67	4	2,750	2,063	3,438	16,592
75	4	5,600	1,975	9,225	9,283
83	4	30	25	35	2,094
88	5	850	488	1,212	3,349
112	4	55	44	66	638

Table 10. Total Coliform Concentration for Mobile Bay - May 1962
Loading at Mobile River Mouth = 1/5
TC_{31} (D.F. = 5)
Correction Factor for E = 500
$K_r = 0.72$ day^{-1}

Station No.	Measured Data				Model Calculated Result
	No. of Field Sampling	Monthly Average $\bar{x}$	70% Confidence Range		
			$\bar{x} - tS_{\bar{x}}$	$\bar{x} + tS_{\bar{x}}$	
33	4	150	56	244	1,515
36	5	91,600	25,077	158,123	18,166
59	4	600	-13	1,213	1,456
60	5	10,600	-1,108	22,308	3,287
61	5	6,000	-1,108	13,108	2,824
62	4	670	91	1,249	1,250
65	4	3,500	906	6,094	638
66	5	5,240	717	9,763	1,523
67	5	20,000	5,578	34,422	1,514
75	5	3,000	925	5,075	582
83	4	19	13	25	72
88	4	260	16	504	434
112	5	12	7	17	22

Table 11. Total Coliform Concentration for Mobile Bay - June 1962
Loading at Mobile River Mouth = 1/4
TC_{31} (D.F. = 4)
Correction Factor for E = 500
K_r = 0.81 day^{-1}

Station No.	Measured Data				Model Calculated Result
	No. of Field Sampling	Monthly Average $\overline{x}$	70% Confidence Range		
			$\overline{x} - tS_{\overline{x}}$	$\overline{x} + tS_{\overline{x}}$	
33	3	250	145	355	70
36	3	600	320	880	293
59	4	12	7	17	26
60	4	25	10	40	61
61	4	50	27	73	81
62	4	110	19	201	124
65	4	20	7	33	12
66	3	7	4	10	26
67	3	132	14	250	46
75	3	20	8	32	16
83	4	10	9	11	1
88	3	15	14	16	7
112	4	10	6	14	1

Table 12. Total Coliform Concentration for Mobile Bay – July 1962
Loading at Mobile River Mouth = 1/6
TC_{31} (D.F. = 6)
Correction Factor for E = 500
K_r = 0.88 day^{-1}

Station No.	Measured Data				Model Calculated Result
	No. of Field Sampling	Monthly Average $\overline{x}$	70% Confidence Range		
			$\overline{x} - tS_{\overline{x}}$	$\overline{x} + tS_{\overline{x}}$	
33	4	360	154	566	249
36	4	300	144	456	1,272
59	4	9	6	12	86
60	4	35	12	58	176
61	4	161	69	101	166
62	4	100	50	150	138
65	4	20	9	31	40
66	4	40	15	65	78
67	4	33	13	53	86
75	4	120	10	230	29
83	5	10	9	11	3
88	5	13	5	21	20
112	5	40	20	60	2

Table 13. Total Coliform Concentration for Mobile Bay - August 1962
Loading at Mobile River Mouth = 1/6
TC_{31} (D.F. = 6)
Correction Factor for E = 500
$K_r = 0.90$ day^{-1}

Station No.	Measured Data				Model Calculated Result
	No. of Field Sampling	Monthly Average $\bar{x}$	70% Confidence Range		
			$\bar{x} - tS_{\bar{x}}$	$\bar{x} + tS_{\bar{x}}$	
33	5	50	32	68	74
36	5	250	160	340	528
59	2	4	2	6	36
60	2	10	8	12	104
61	2	15	1	31	162
62	3	15	12	18	282
65	3	10	3	17	15
66	3	7	4	10	40
67	3	5	4	6	89
75	4	4	3	5	27
83	4	8	5	11	1
88	3	3	2	4	8
112	4	7	1	13	1

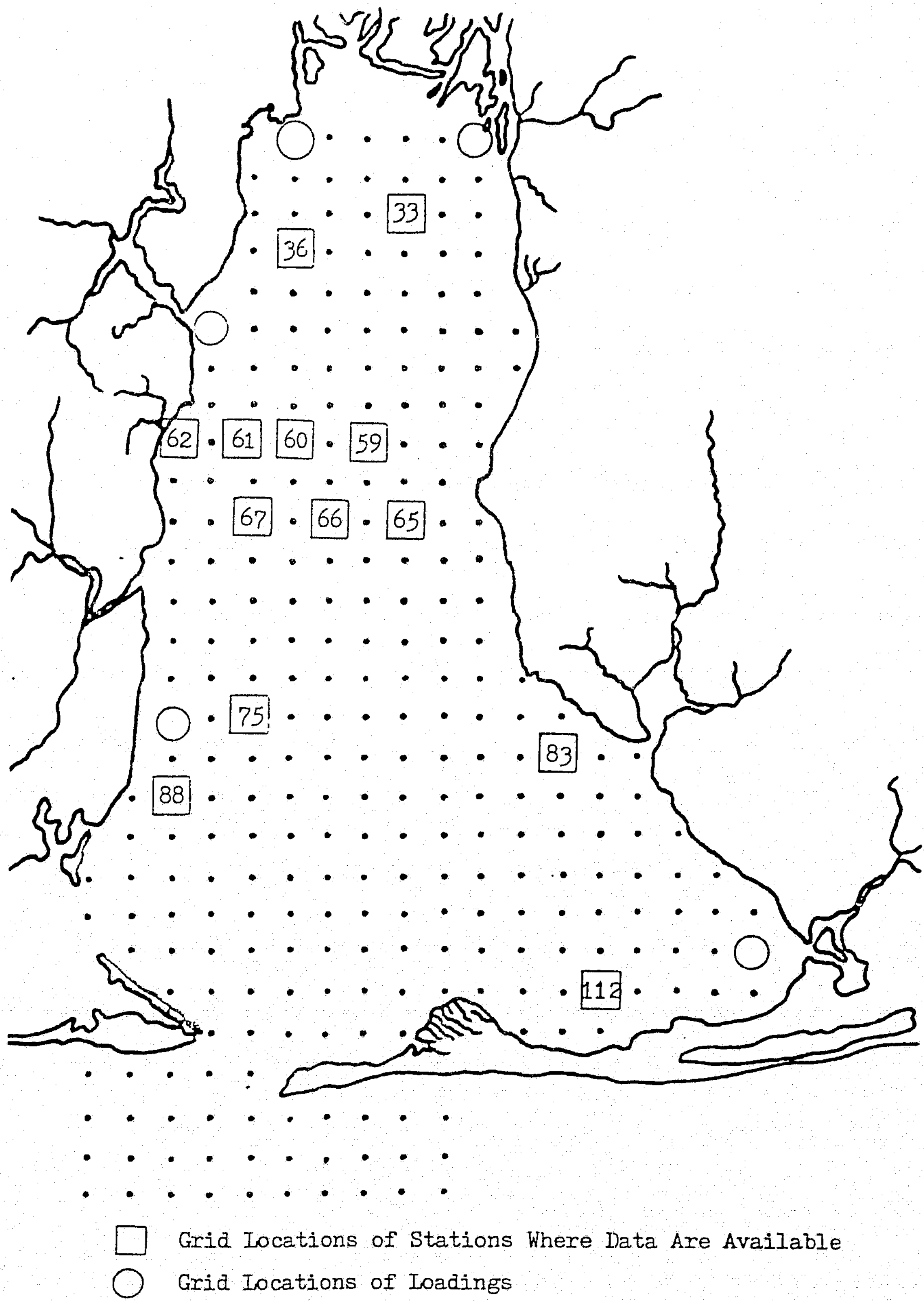


Figure 14. Locations of Total Coliform Stations and Loadings

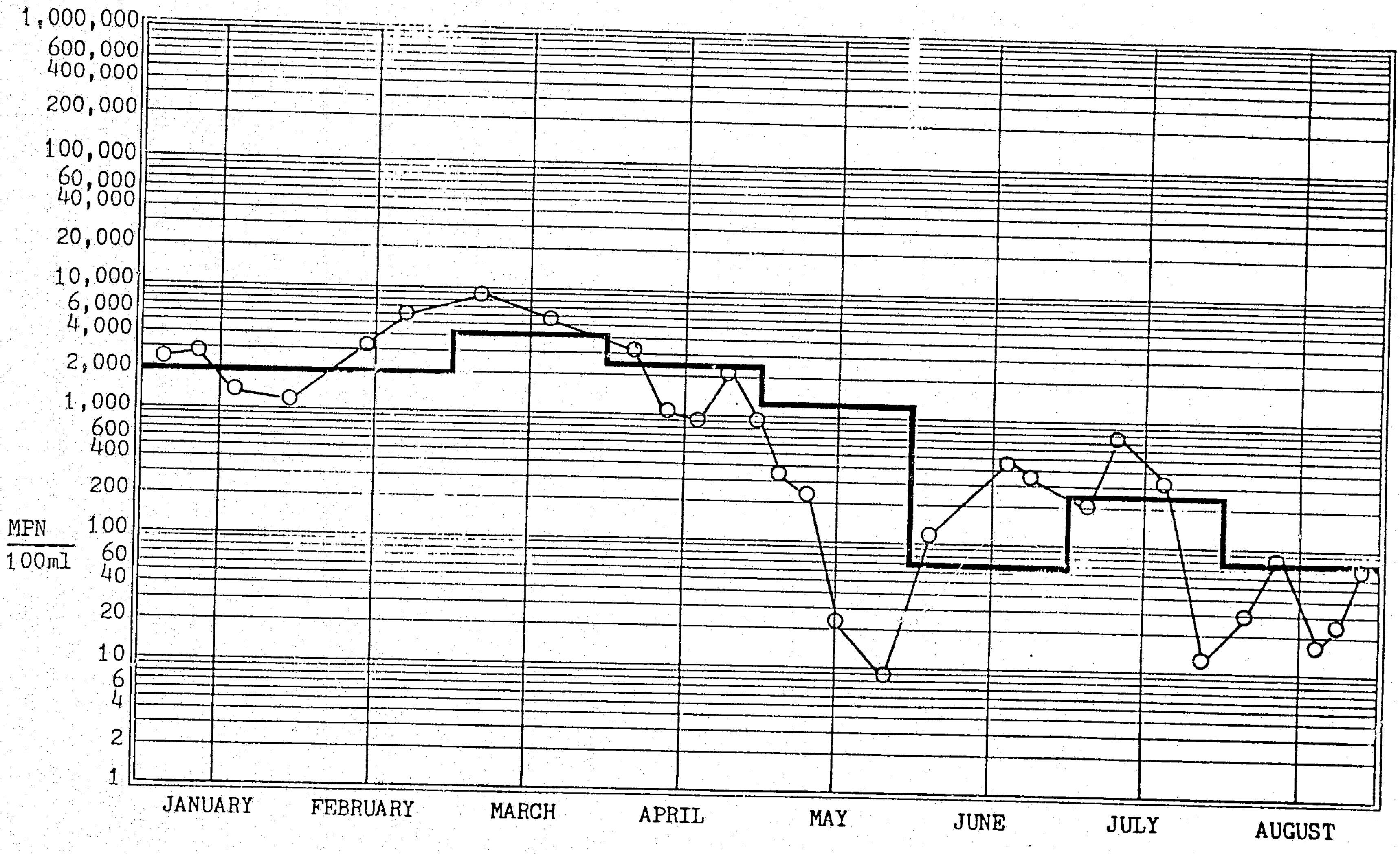


Figure 15. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 33.

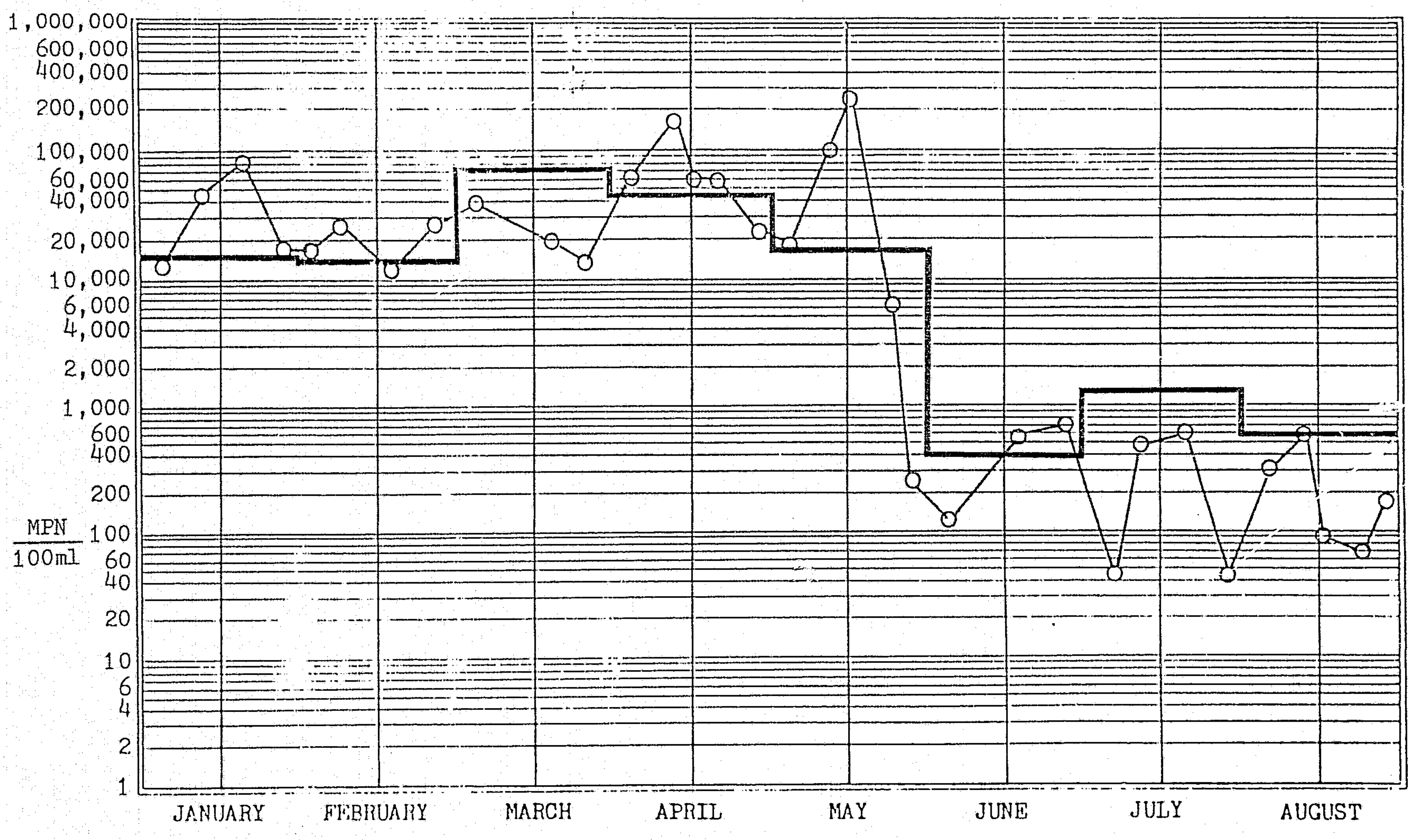


Figure 16. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 36.

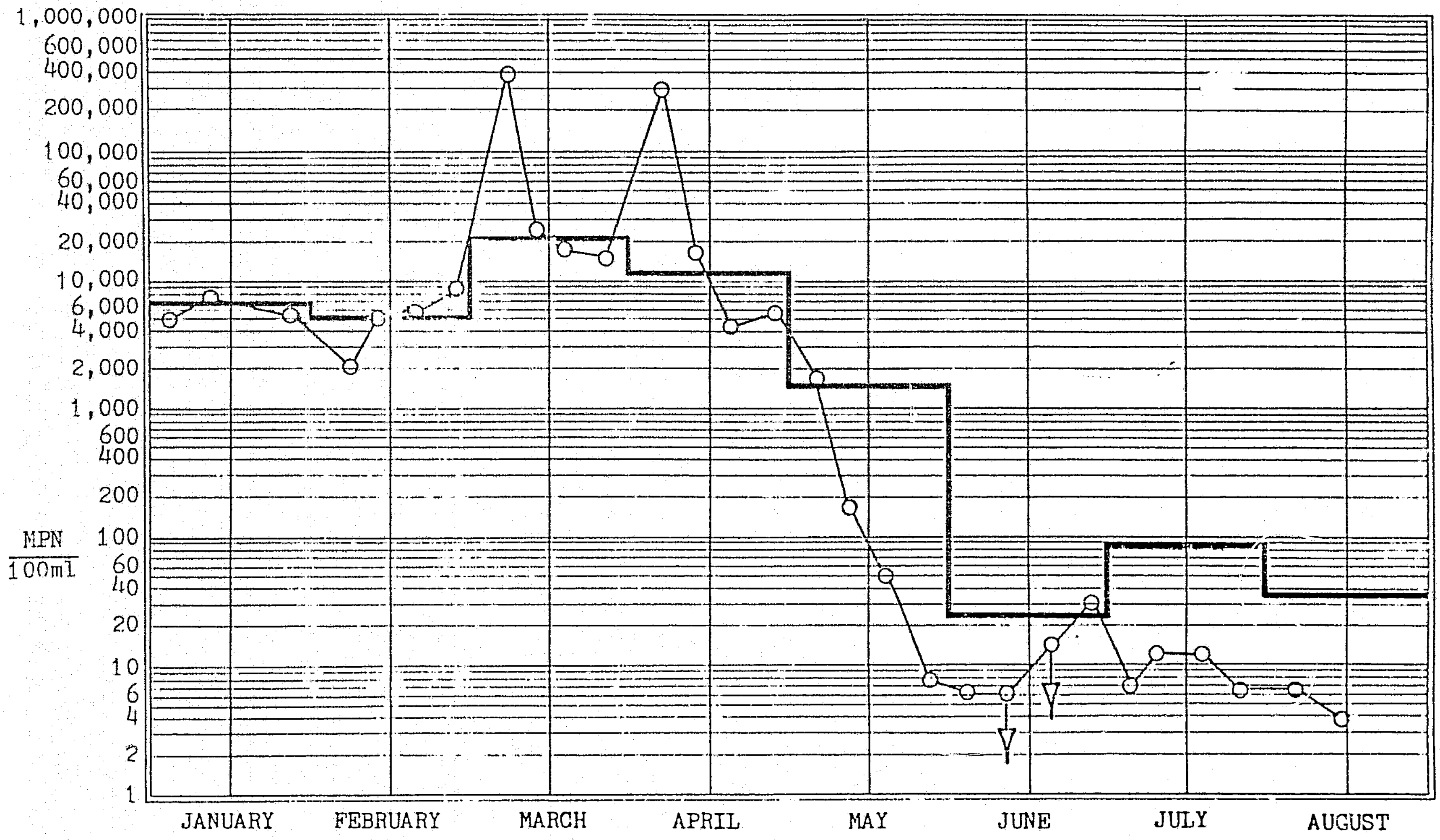


Figure 17. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 59.

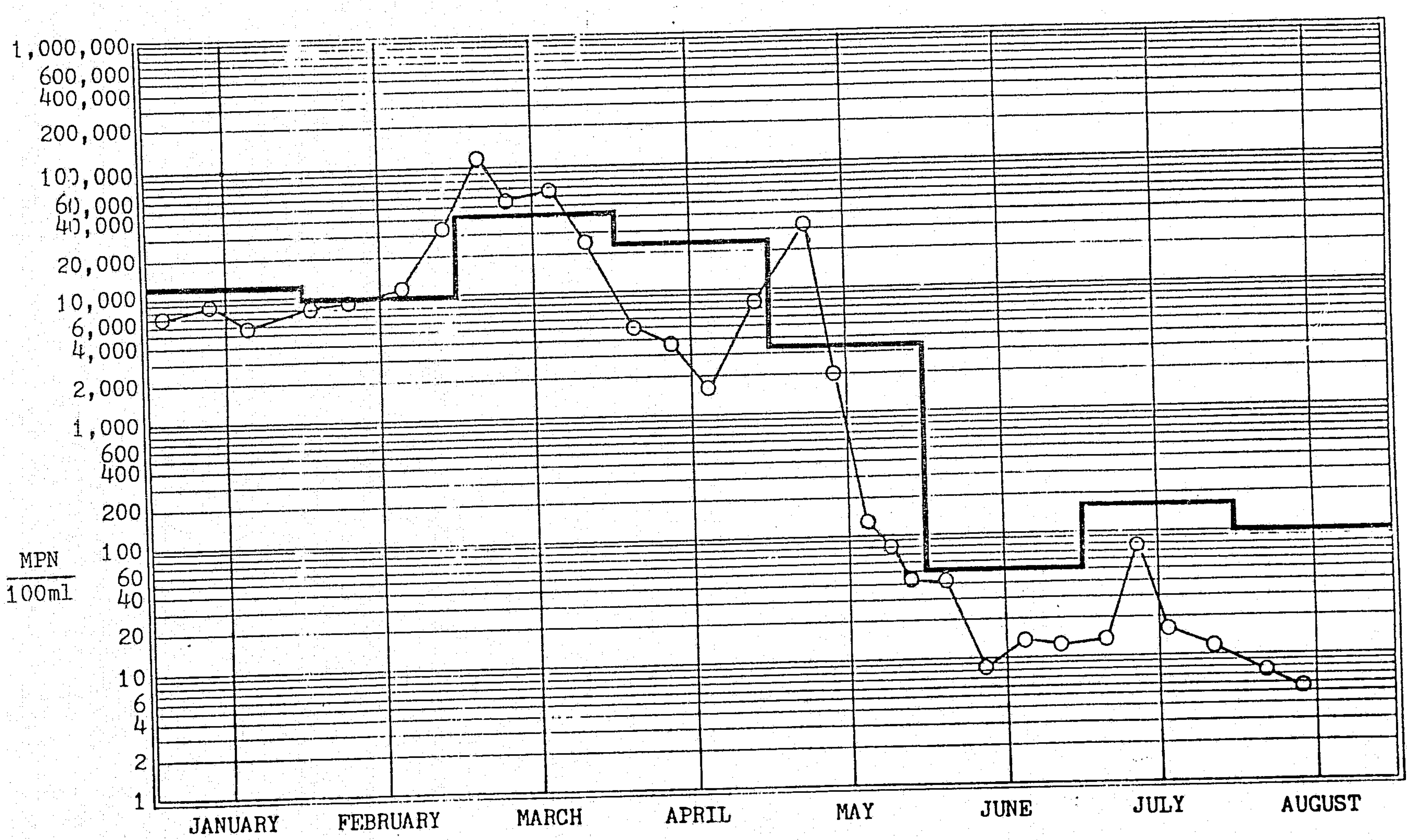


Figure 18. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 60.

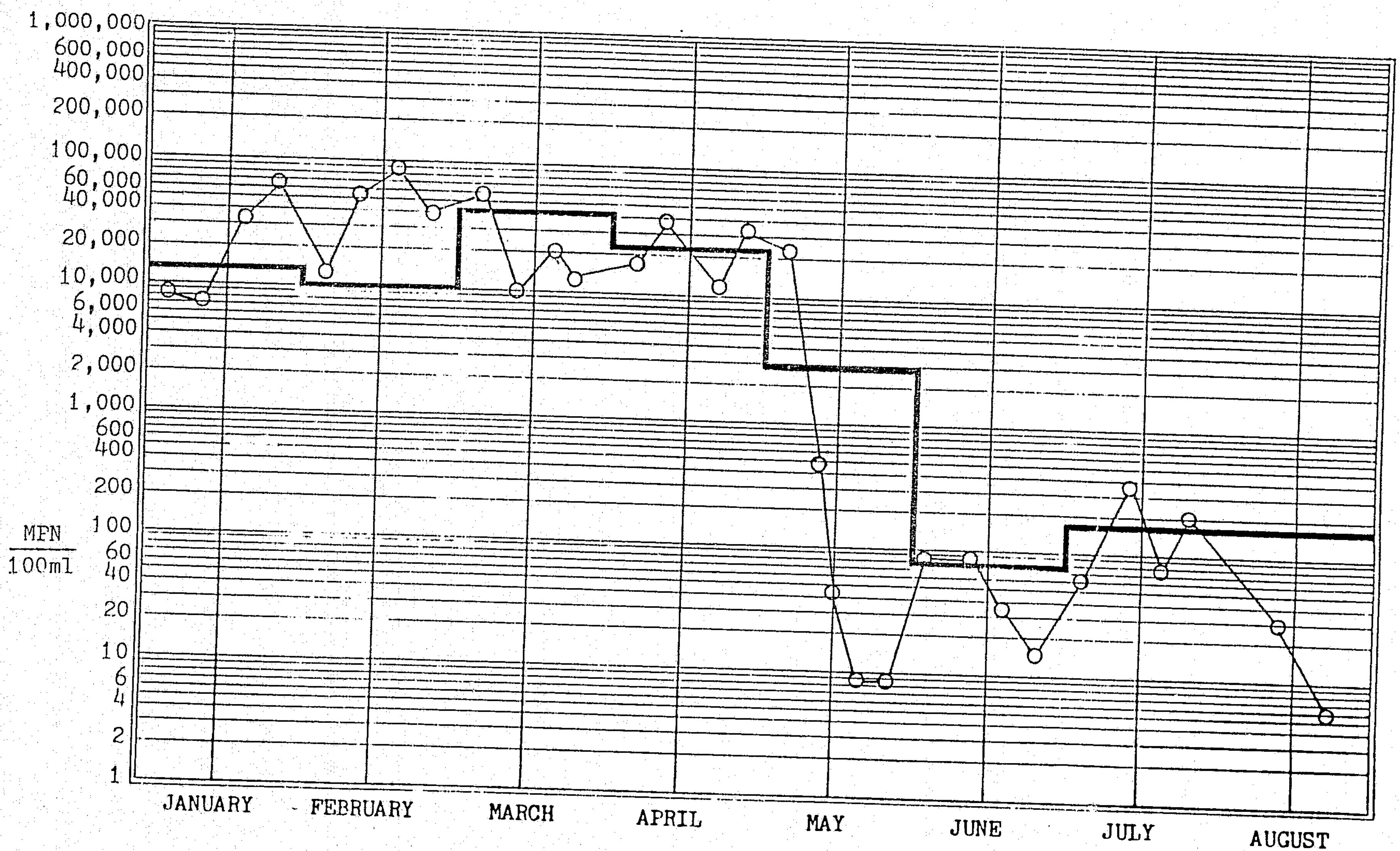


Figure 19. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 61.

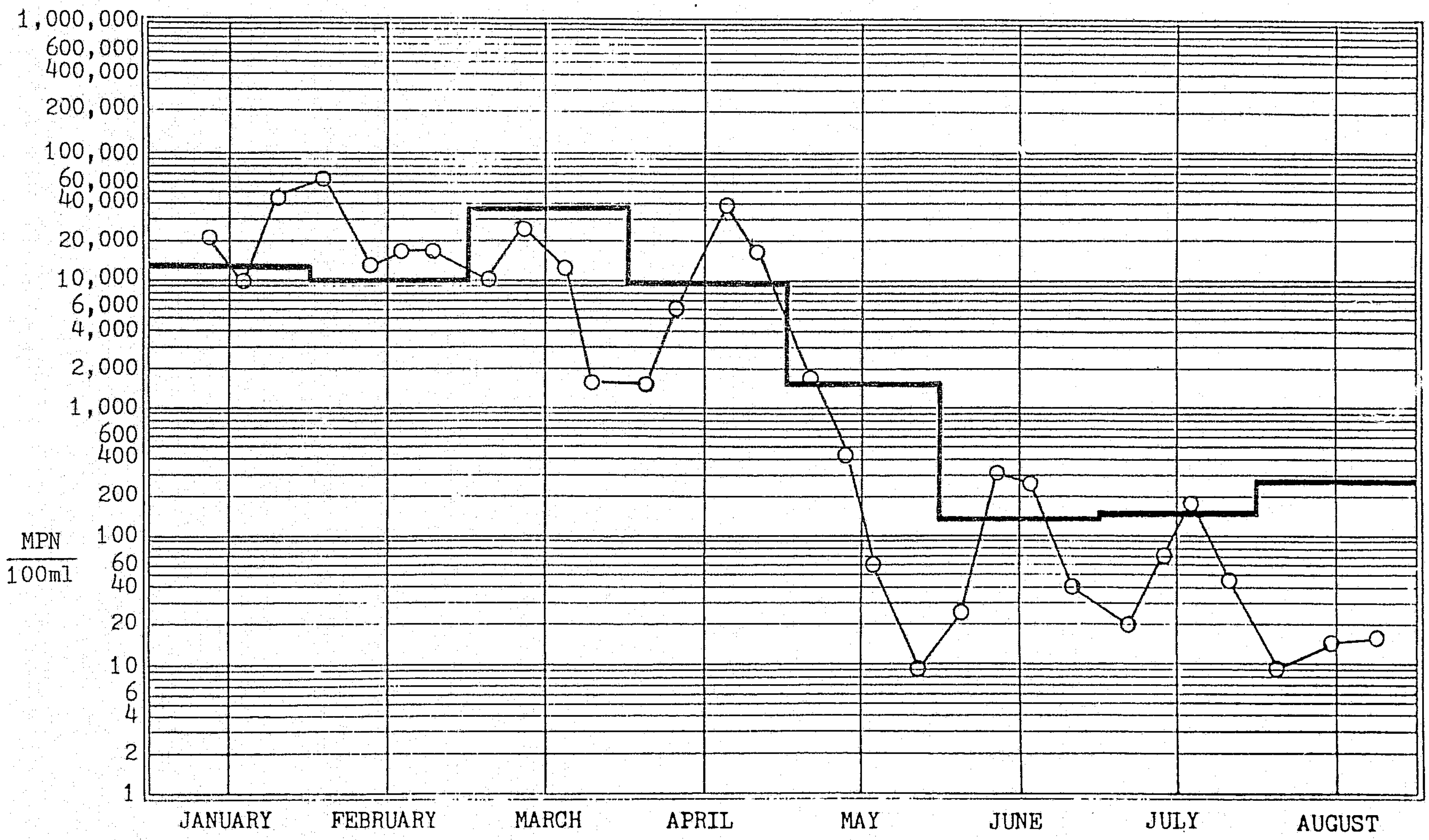


Figure 20. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 62.

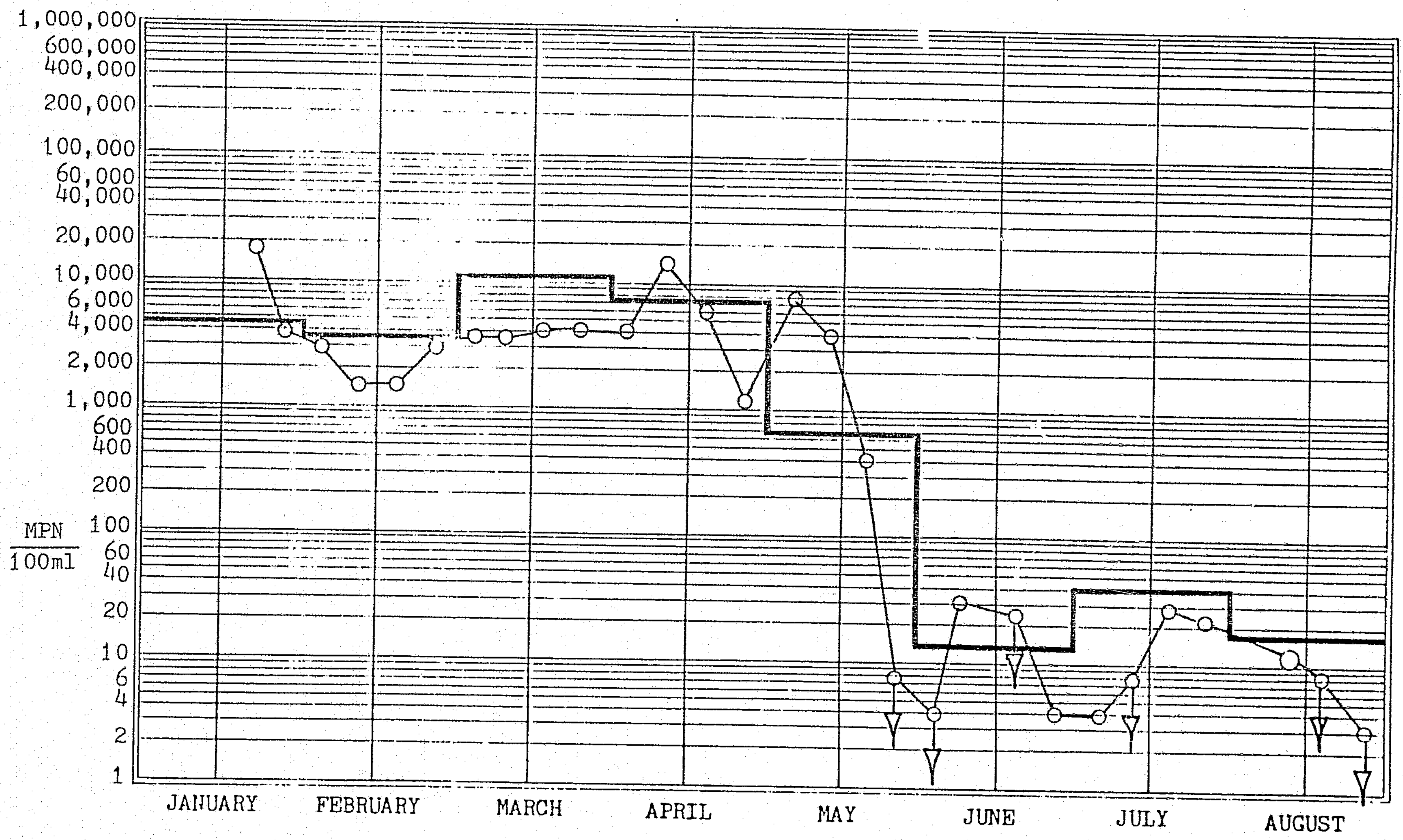


Figure 21. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 65.

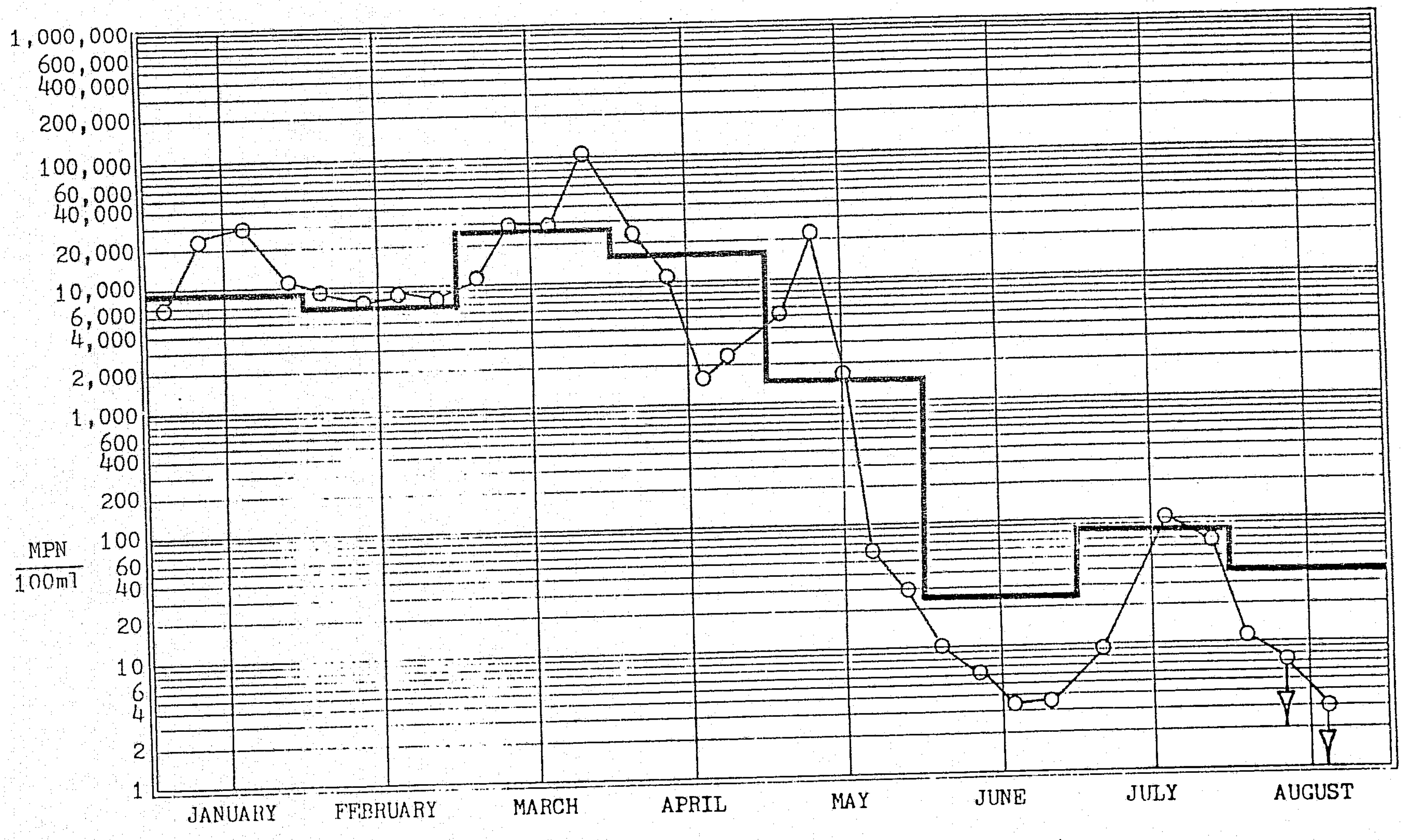


Figure 22. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 66.

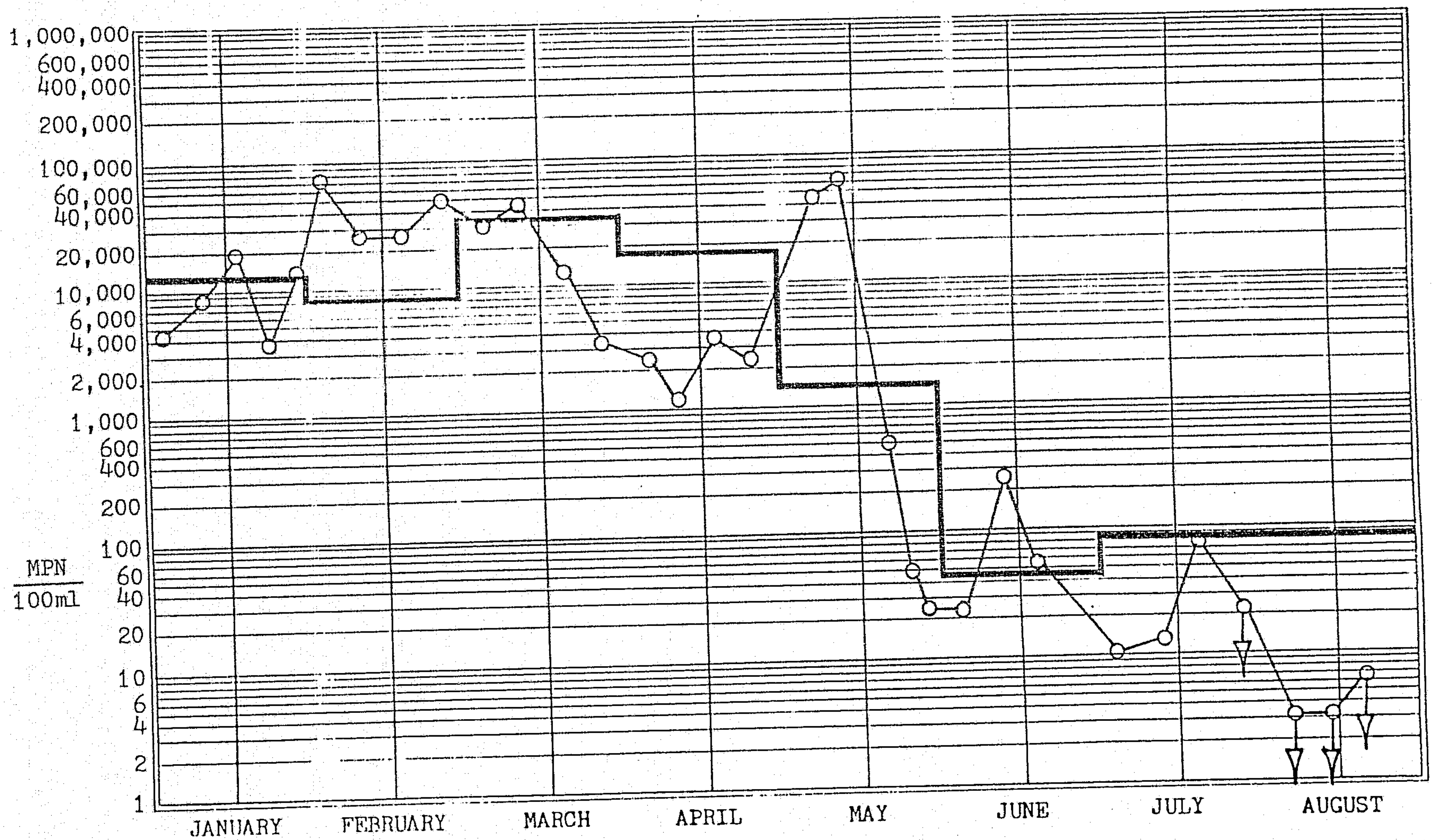


Figure 23. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 67.

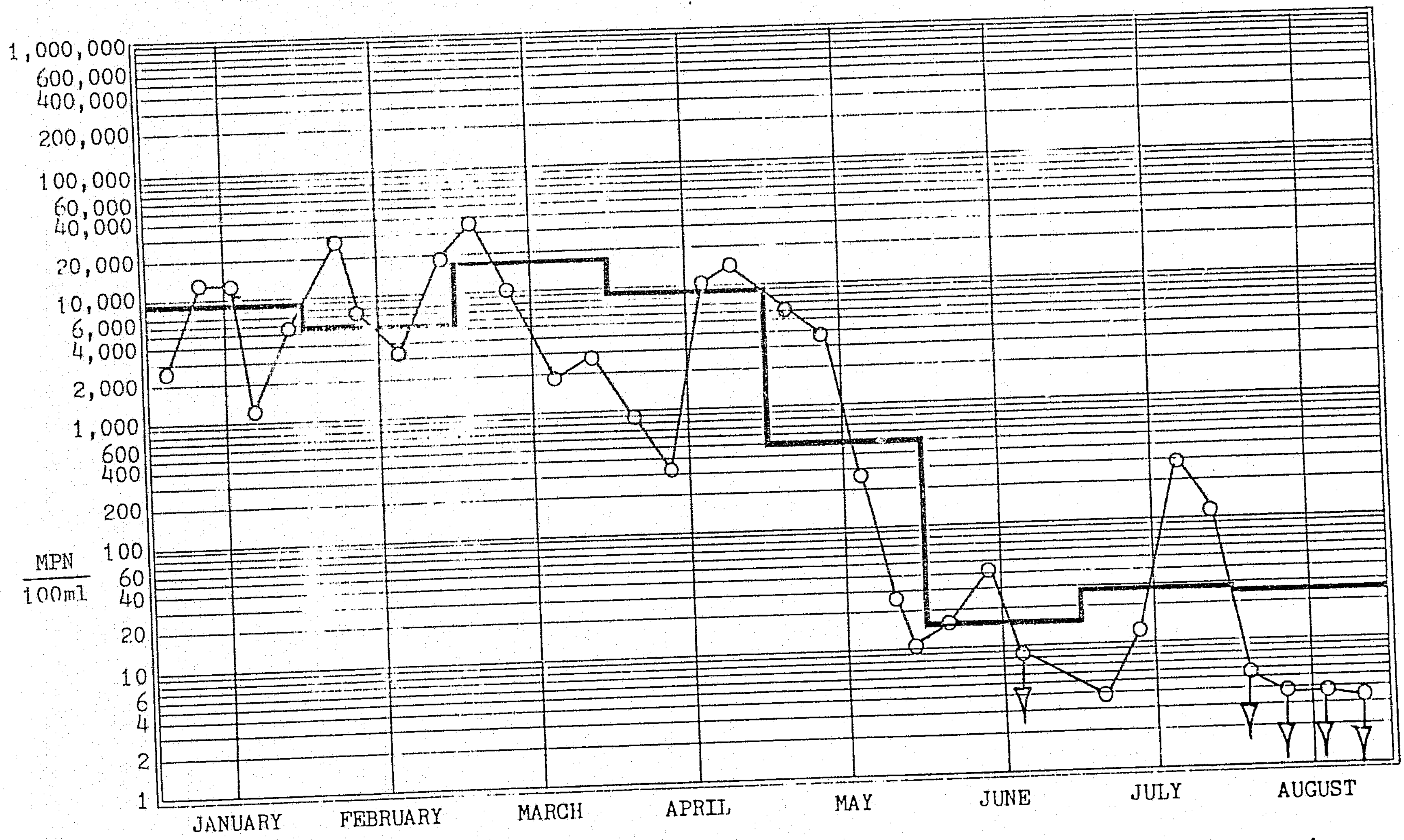


Figure 24. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 75.

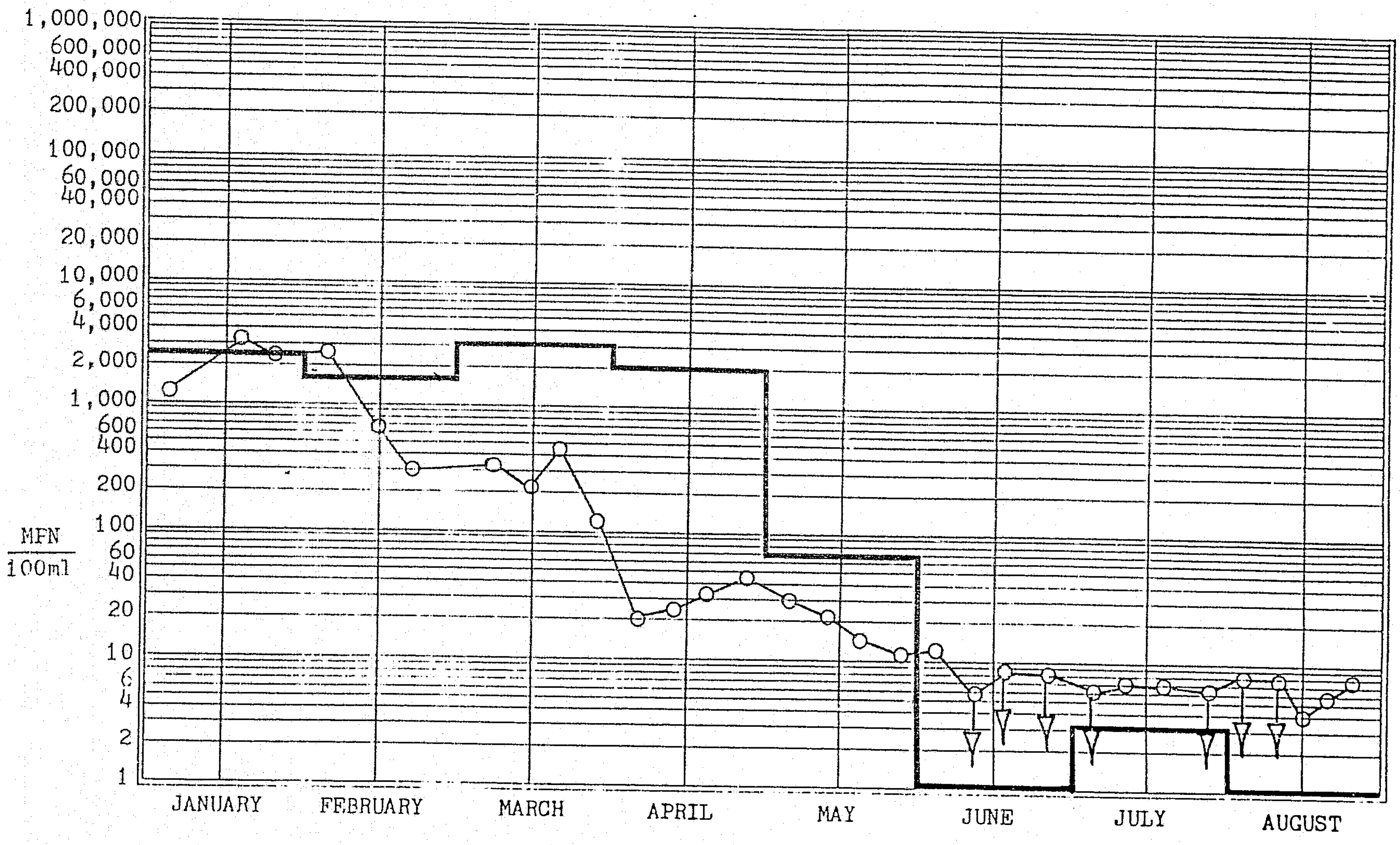


Figure 25. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 83.

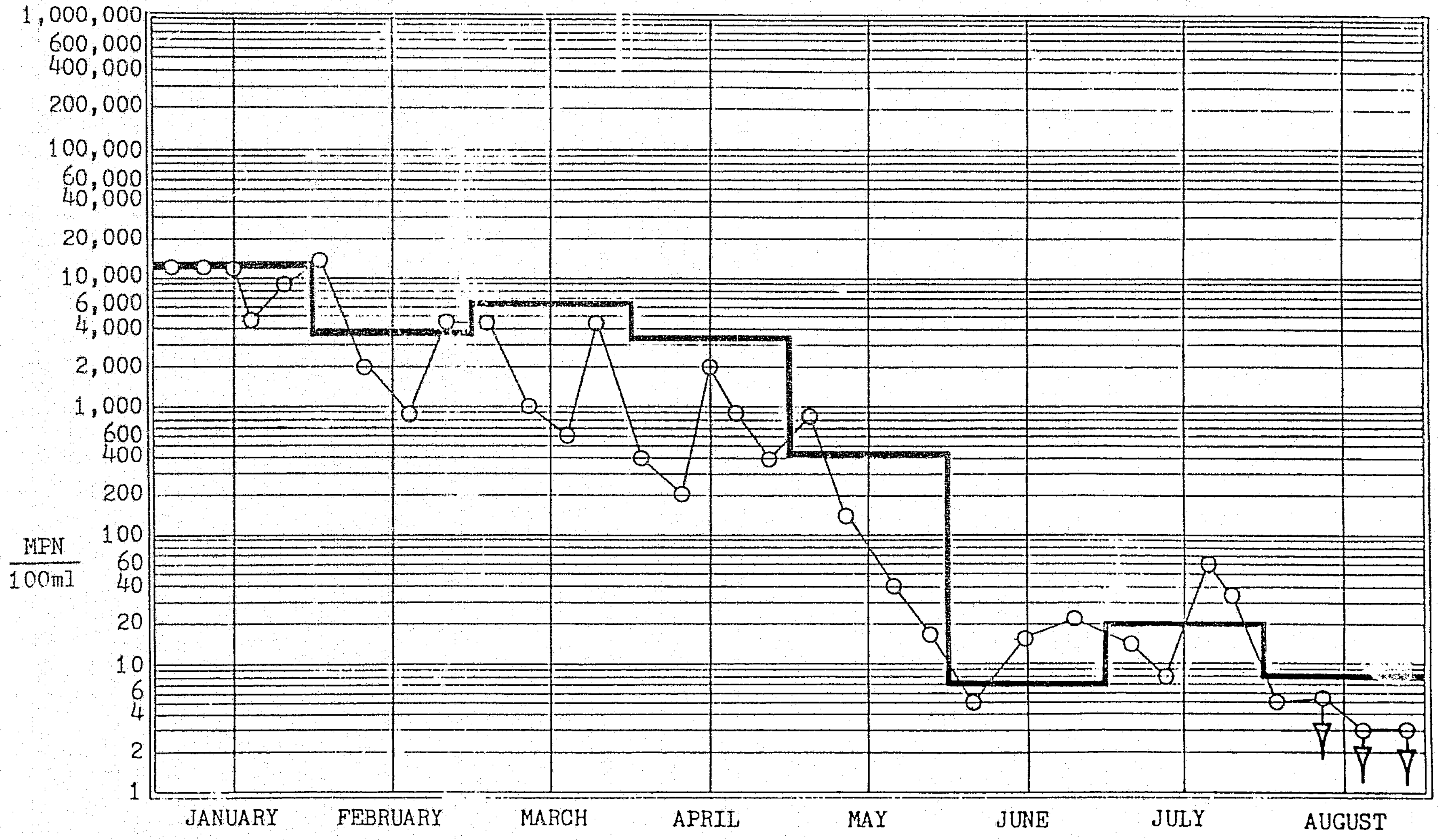


Figure 26. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 88.

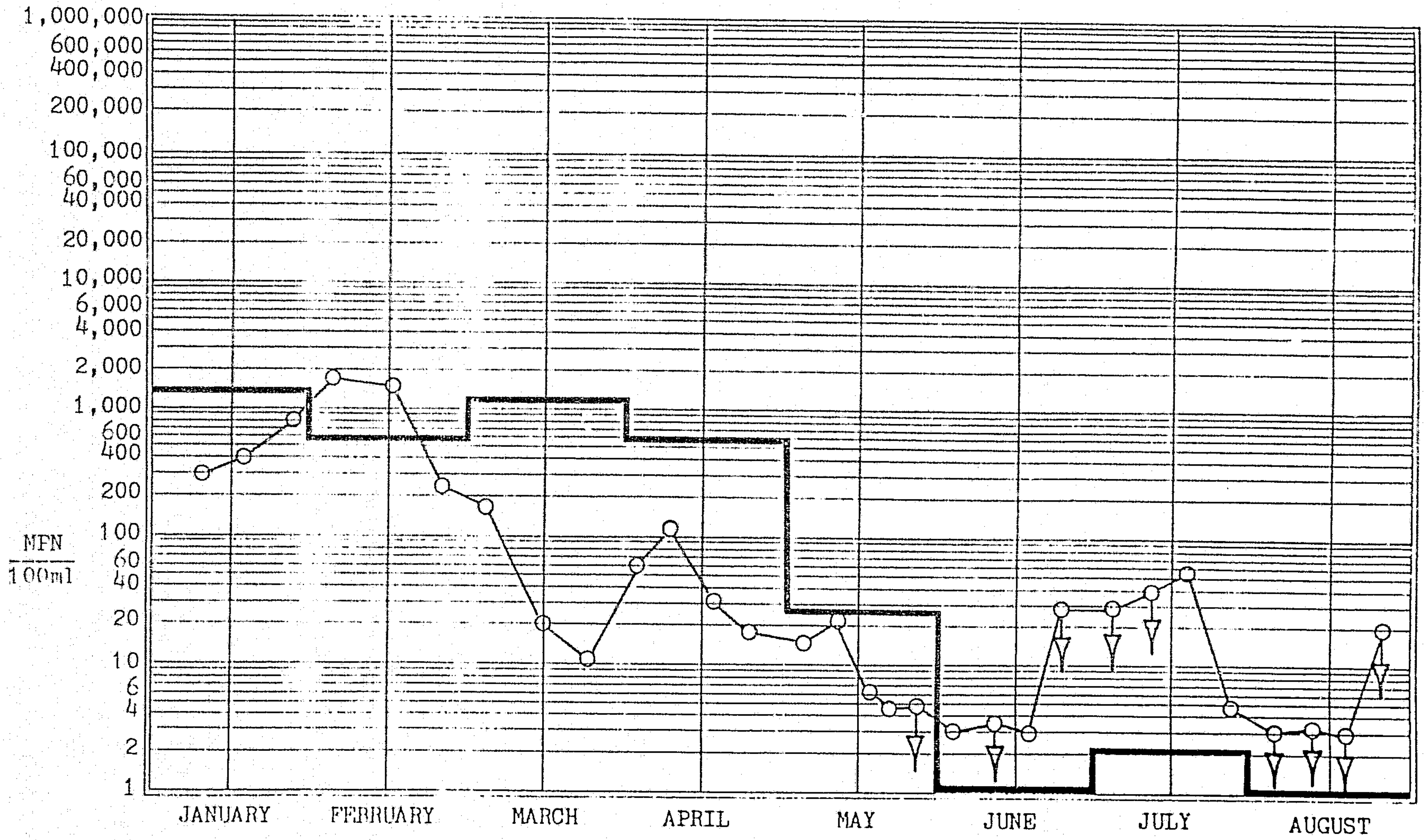
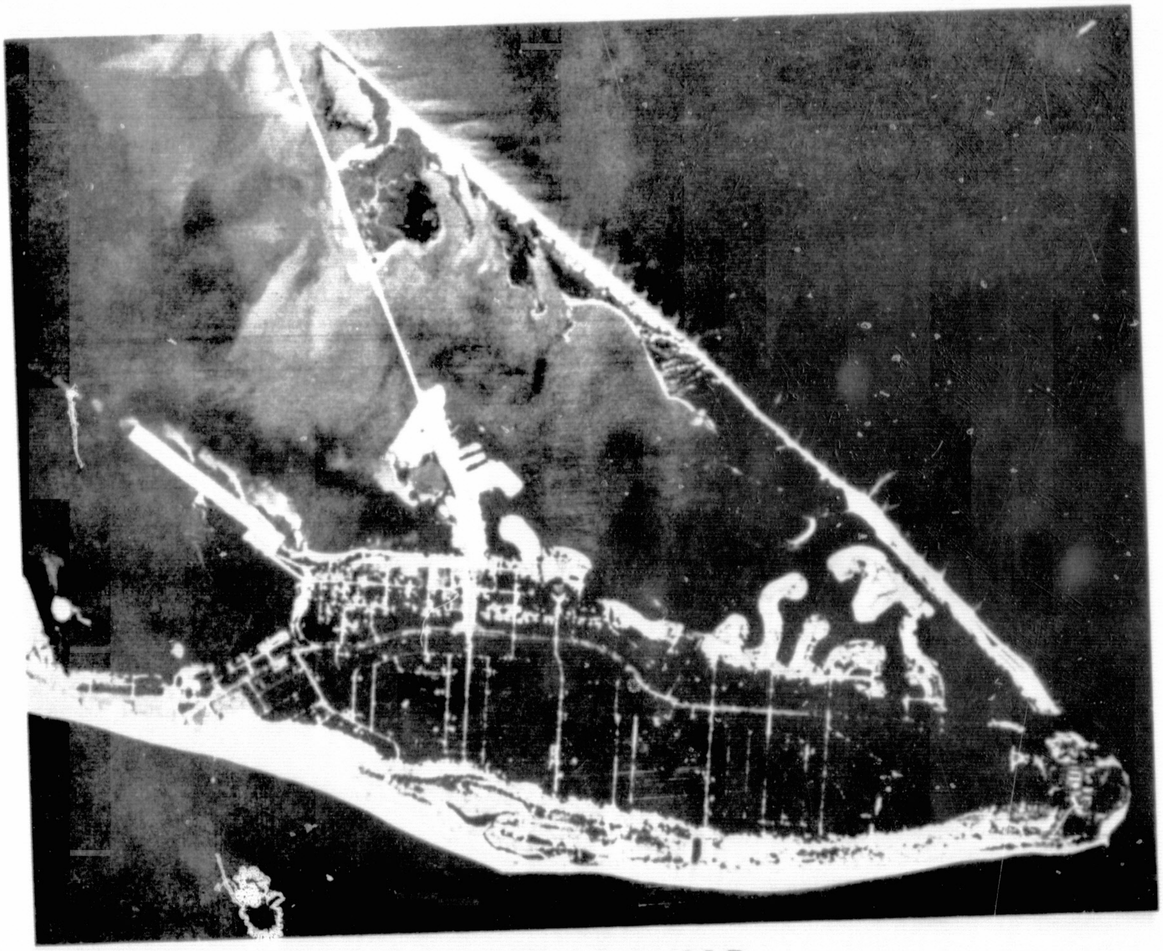


Figure 27. Model Calculated Averages Compared with Actual Data of Total Coliform Concentration at Station No. 112.

Table 14. Seasonal Average River Flow Rates and Sediment Load for the Mobile Bay System; 1952-1962 (U.S. Corps of Engineers, 1974).

River Flow Rate Classification	Period Covered	Average Flow Rate ft^3/sec	Flow Rate (Range) ft^3/sec	Average Sediment Load tons x 10^{-3}	Sediment Load (Range) tons x 10^{-3}
Low	August-November	18752	15785-24720	75	55-118
Medium	May-July	38492	28287-66820	237	159-389
High	December-April	105165	56820-135923	750	389-1030
	Annual Averages	56820		398	



WATER RESOURCES PLANNING
FOR
RIVERS DRAINING
INTO
MOBILE BAY

INFLUENCE OF SYSTEM CHANGES
ON MOBILE BAY BEHAVIOR

THE INFLUENCE OF SYSTEM CHANGES ON MOBILE BAY BEHAVIOR

In order to assess the impact that changing river flow rates, wind conditions, coliform bacteria, sediment loading concentration and water temperature have on the hydrodynamic and material transport properties of Mobile Bay, a parametric study was conducted using the developed and verified mathematical models. The results of this study are discussed in the following sections, subdivided for clearer presentation of the material.

Hydrodynamic and Salinity Models

There are two major areas of interest for consideration in this section. These areas include the effects of several model parameters and the effect of variations in natural phenomena on the system behavior. Specifically, the model parameters studied are: (1) convective acceleration, (2) Coriolis force, (3) a non-traditional method for calculating the resistance term and (4) simulation of the salinity wedge effect. To measure the influence that each of these parameters had on the hydrodynamic and salinity transport behavior of the bay, three levels of fresh water flow (12,000 cu.ft./sec., 44,000 cu.ft./sec., 245,000 cu.ft./sec.) and two levels of wind (15 knots, 25 knots; both from the prevailing wind direction) were investigated. For purposes of discussion, river flows will be held constant and comparisons made among the other parameters. Following comparisons at each river flow, observations will be made relating to the effects of variations in fresh water input. Tables contrasting tidal conditions, tide height curves predicted by the model superimposed with the actual data used in the verification study and salinity profiles will be presented.

Low River Flow - The lowest river flow considered was 12,000 cubic feet per second for the Mobile River complex plus an additional 5000 cubic feet per second superimposed on Dog River. Tidal information for high and low water is presented in Table 15 for State Docks, Point Clear, Fowl River and Bon Secour River. The first column in Table 15 and all subsequent tables is considered to be the standard for comparison in that table.

Wind direction throughout these studies was held constant at an angle of 200° measured clockwise from the north (southwest wind). This particular direction was chosen since it approximates the prevailing winds in this area. Magnitudes of velocity were set at fifteen and twenty-five knots. It will be noted in the tables that wind from the southwest increases both maximum and minimum tidal amplitudes.

Variations in salinity profiles are most significant. It can be noted in Figure 28 that the southwest wind pushes the fresh water toward the east and thus increases the salinity intrusion up the western side of the bay. It should be noted, also, that little happens in the

Table 15. Extreme Tidal Elevations (Feet) from Mean Sea Level for Low River Flow Conditions (12,000 cfs).

Run Number	1	2	3	4	5	6
Wind Condition						
Speed, knots	0	15	25	0	0	0
Direction	SW	SW	SW	SW	SW	SW
Convective Acceleration	YES	YES	YES	NO	YES	YES
Coriolis Force	YES	YES	YES	YES	NO	YES
Resistance Calculation						
Standard	YES	YES	YES	YES	YES	NO
Modified	NO	NO	NO	NO	NO	YES
State Docks						
High Tide	2.57	2.78	3.77	2.60	2.57	2.65
Low Tide	-0.24	0.30	1.67	-0.42	-0.24	-0.50
Point Clear						
High Tide	2.53	2.66	3.21	2.53	2.53	2.54
Low Tide	-0.27	-0.02	0.80	-0.36	-0.24	-0.41
Fowl River						
High Tide	2.51	2.61	3.05	2.52	2.52	2.54
Low Tide	-0.23	-0.01	0.67	-0.33	-0.22	-0.39
Bon Secour River						
High Tide	2.45	2.51	2.74	2.45	2.46	2.50
Low Tide	-0.20	-0.12	0.29	-0.26	-0.17	-0.35

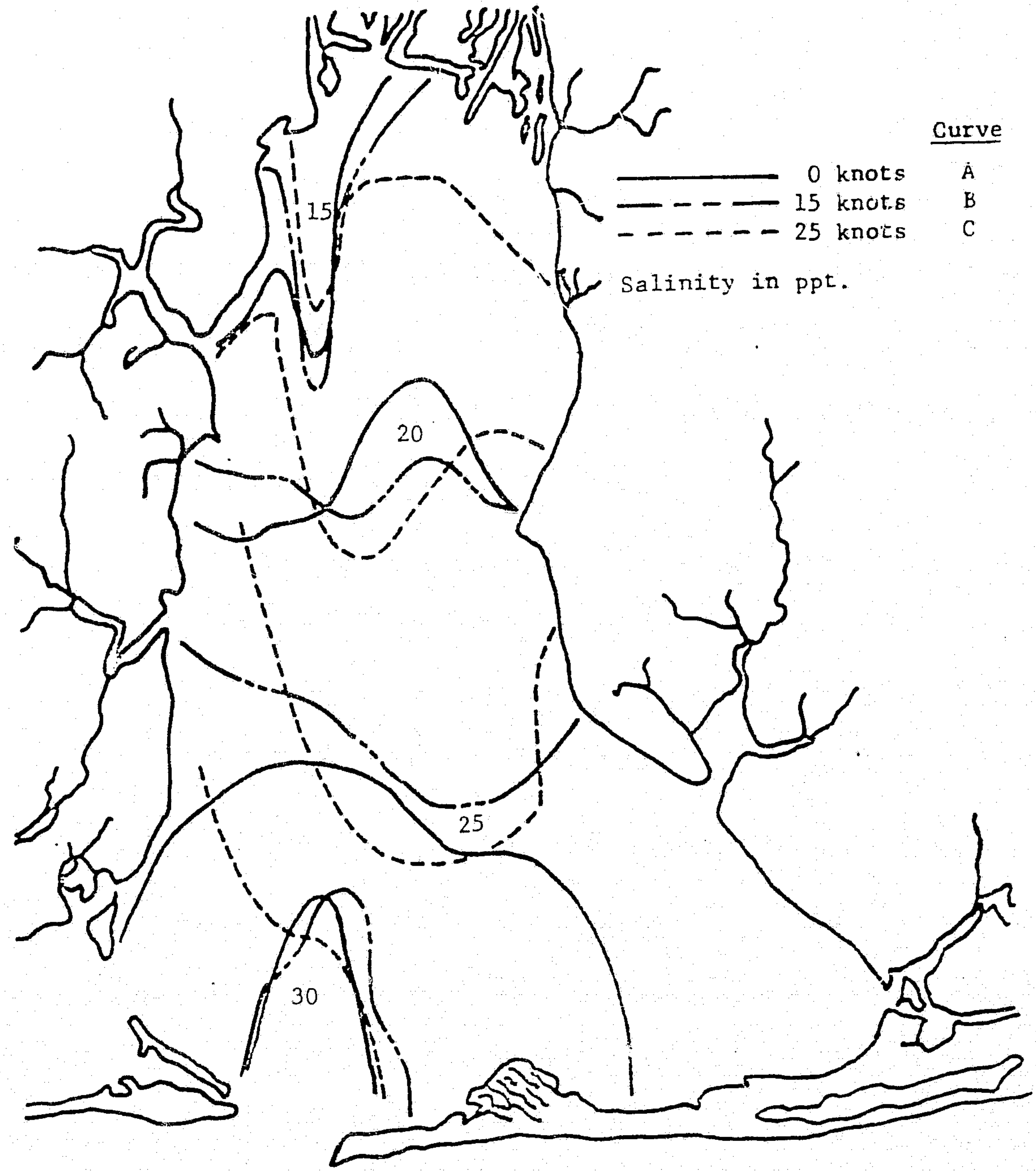


Figure 28. Effect of Southwest Wind Speed on Salinity Distributions in Mobile Bay for a 12,000 cfs River Flow in Mobile River.

eastern portion of Bon Secour Bay. This aspect should be kept in mind and observed in the other parametric studies as comparisons are made. The significance of this phenomenon lies in considerations of this area for proposed industrial developments, power generating plants or municipal discharges as flushing characteristics are likely to be minimal.

Referring again to Table 15 the effects of convective acceleration, Coriolis force and the modified resistance term can be assessed in terms of tidal amplitudes at high and low water. Comparing Run 1 with Run 4, it can be seen that considerable variations in tidal conditions exist. The impact on salinity profiles can be observed in a comparison of curves A and B in Figure 29.

The Coriolis force appears to have very little effect on tidal elevations, comparing results for Run 1 with Run 5. Surprisingly, however, the effect on salinity appears to be significant. This is especially true for the isohaline for twenty-five parts per thousand as can be noted by curve C in Figure 29. Since the ultimate use of the hydrodynamic model is for the purpose of generating data for transport models such as salinity, dissolved oxygen and biochemical oxygen demand, the Coriolis force is judged to be essential in the Mobile Bay model.

The modified resistance term is questionable in some respects and promising in others. Model stability appears to be unaffected and some savings in computing time can be realized. However, results indicate that resistance has been minimized while the opposite was expected. Salinity effects are equally surprising. Comparing curves A and D in Figure 29, it will be noted that curve D for the modified resistance term is a closer approximation of field data than was the verification profile which is shown as curve A.

<u>Medium River Flows</u> - An intermediate river flow for this study was chosen to be 44,000 cubic feet per second for the Mobile River complex and 5,000 cubic feet per second for Dog River. This flow regime is analogous to that used in the verification run for the hydrodynamic model.

Wind effects on tidal amplitudes at medium river flows are very similar to those at low flow as was expected. Numerical comparisons can be made in Table 16. It should be noted that effects of the fifteen knot wind on tidal amplitudes are essentially negligible for Point Clear, Fowl River and Bon Secour while there is significant changes at State Docks. Tidal effects are expected to be magnified at the latter location due to the convergence of land boundaries in the northern part of Mobile Bay.

Variations in salinity patterns may be noted from a comparison of curve A with curve B and C in Figure 30. Again, it is interesting to note the apparent shift in fresh water flow toward the east that results from wind drag. The shape of the isohalines are essentially reversed from a generally parabolic profile pointing north for low winds to a

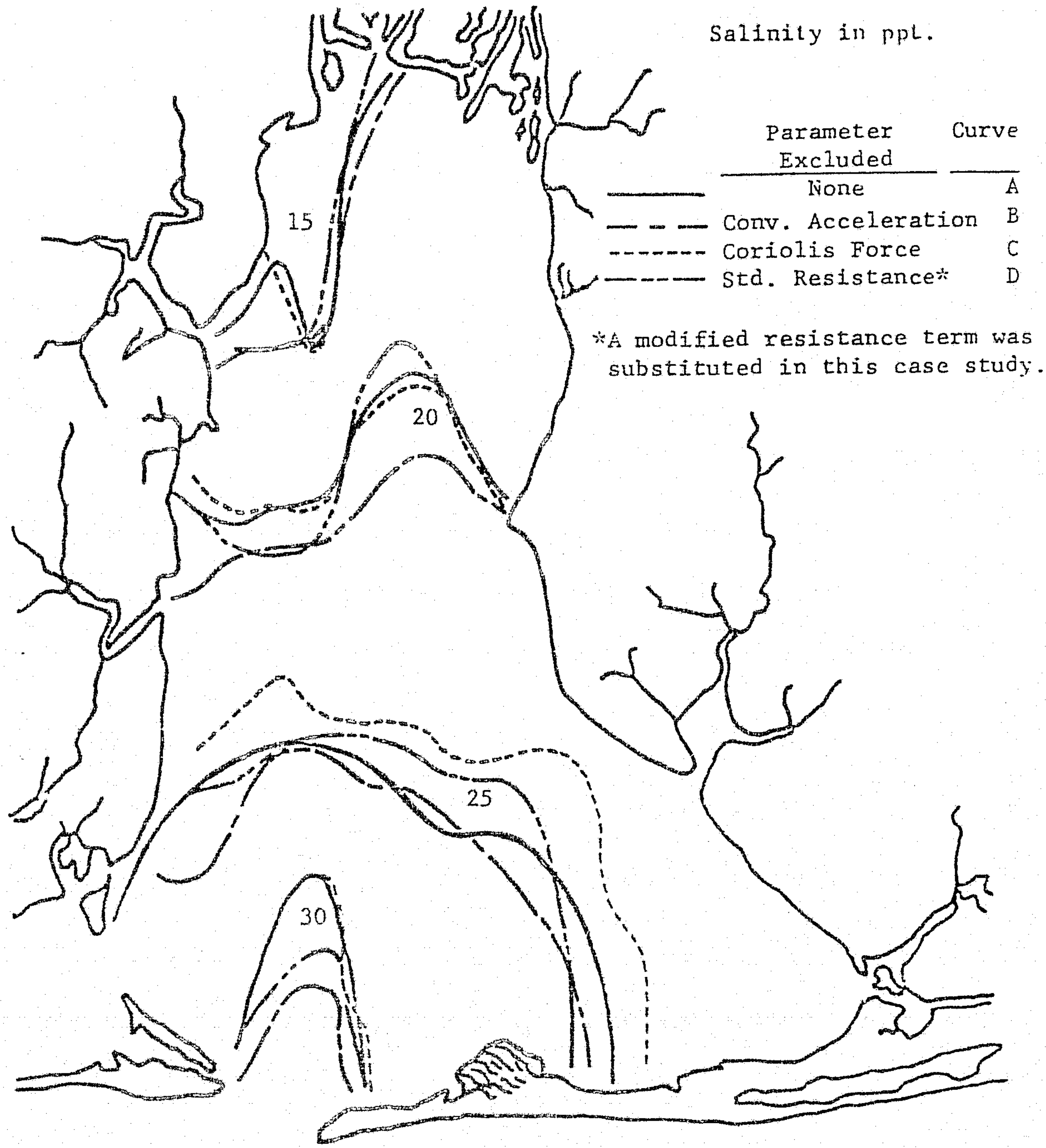


Figure 29. The Influence of Model Parameters on the Salinity Distributions in Mobile Bay for a 12,000 cfs River Flow in Mobile River.

Table 16. Extreme Tidal Elevations (Feet) from Mean Sea Level for Medium River Flow Conditions (44,000 cfs).

Run Number	7	8	9	10	11	12
Wind Condition						
Speed, knots	0	15	25	0	0	0
Direction	SW	SW	SW	SW	SW	SW
Convective Acceleration	YES	YES	YES	NO	YES	YES
Coriolis Force	YES	YES	YES	YES	NO	YES
Resistance Calculation						
Standard	YES	YES	YES	YES	YES	NO
Modified	NO	NO	NO	NO	NO	YES
State Docks						
High Tide	2.60	2.84	3.87	2.61	2.60	2.64
Low Tide	0.05	0.57	1.87	-0.12	0.05	-0.24
Point Clear						
High Tide	2.50	2.67	3.23	2.50	2.51	2.50
Low Tide	-0.19	0.01	0.83	-0.29	-0.17	-0.35
Fowl River						
High Tide	2.49	2.62	3.07	2.49	2.50	2.51
Low Tide	-0.14	0.02	0.72	-0.25	-0.15	-0.33
Bon Secour River						
High Tide	2.41	2.50	2.75	2.40	2.43	2.45
Low Tide	-0.14	-0.11	0.31	-0.20	-0.12	-0.21

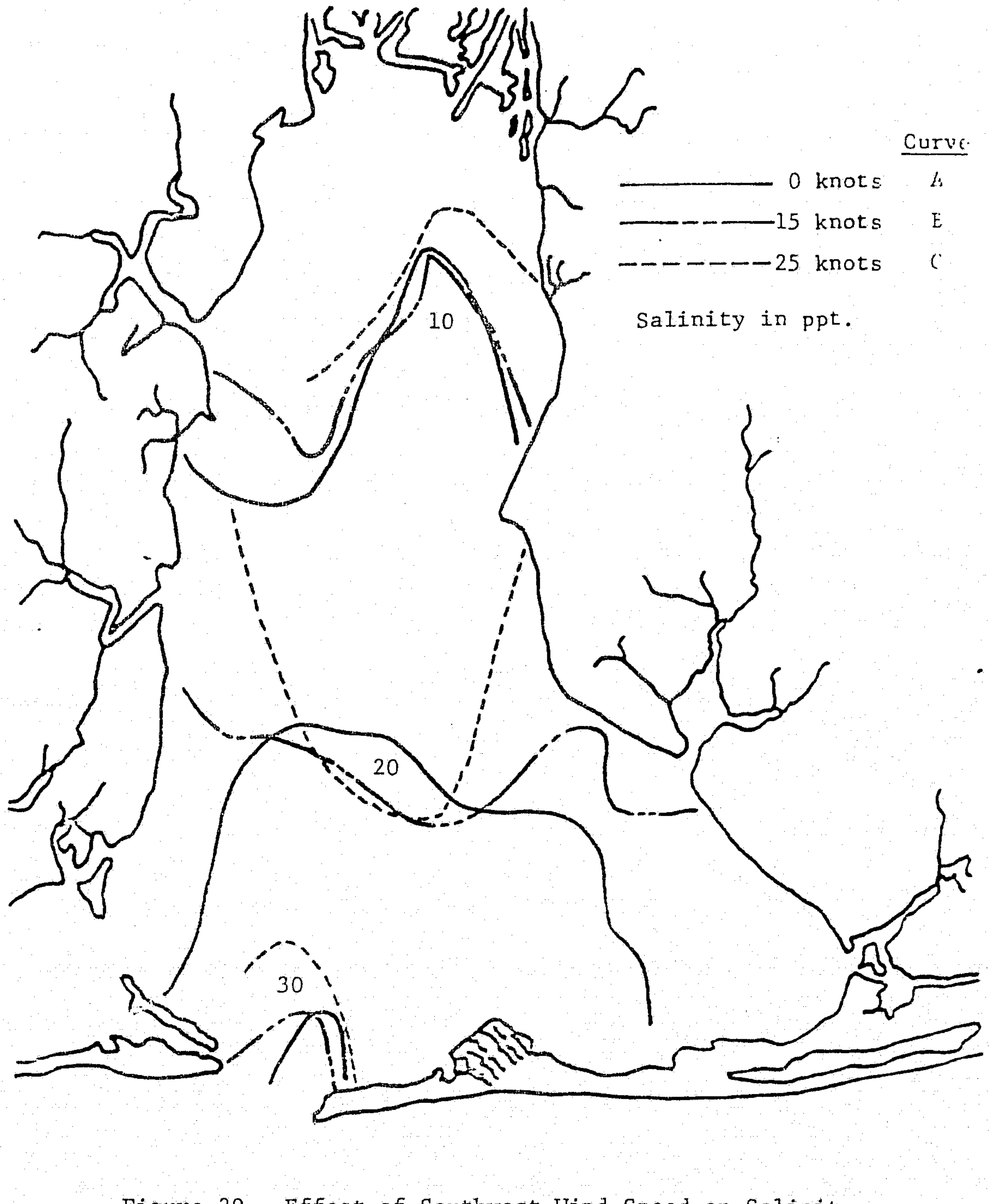


Figure 30. Effect of Southwest Wind Speed on Salinity Distributions in Mobile Bay for a 44,000 cfs River Flow in Mobile River.

parabolic profile pointing south at high winds. The western tip of the isohaline for twenty parts per thousand shifts in a northerly direction some fourteen kilometers for the fifteen knot wind and approximately twenty-seven kilometers for the twenty-five knot wind. The latter distance is approximately two-thirds the length of the bay. Other comparisons can be made with similar results. One significance of this phenomenon is the necessity of specifying wind conditions with salt concentration measurements in the bay.

Referring again to Table 16, it can be observed that contributions of convective acceleration and Coriolis force to tidal heights are similar to those observed previously. There appears to be a significant contribution by the convective acceleration terms and essentially no contribution by the Coriolis force term.

Effects of the convective acceleration and Coriolis terms on the salt profiles can be seen from a comparison of curve A with curves B and C in Figure 31. Changes resulting from the convective acceleration are more pronounced in the lower portion of the bay near Main Pass where this term is expected to have its greatest effect. Coriolis force effects are considerably more subtle. Slight changes are noted in the shape of the curves, but the distribution of salt is, for all practical purposes, the same.

Results affected by the modified resistance term may be seen quantitatively in Table 16. Maximum tide elevations are higher and minimum tide elevations are lower with the modified resistance term than those demonstrated by the standard method.

Salinity profiles using the modified resistance (curve D, Figure 31) are quite similar to those using the standard procedures. The change that may be significant lies in the fifteen parts per thousand isohaline. The western tip is approximately two kilometers further south giving a curve that is somewhat more consistent with observed field data.

High River Flow - Fresh water flows in excess of two hundred thousand cubic feet per second have been observed in the Mobile River system. During April of 1973, flows reached two hundred forty-five thousand cubic feet per second as reported unofficially by the U. S. Geological Survey. Some salinity data was received from the Marine Science Programs, Dauphin Island, Alabama, for this period which indicated that the salt concentrations near the Main Pass ranged from approximately zero at the surface to thirty-two parts per thousand near the bottom. This data is limited to the area adjacent to Main Pass and was not taken over a tidal cycle, therefore, it is difficult to apply as a quantitative check on the model. It is known, however, that significant salt concentrations were noted in the area specified. Tabulated data related to the predicted tidal elevations and graphical results concerning salinity profiles are shown in Table 17 and Figures 32, 33, 34, respectively.

Referring to Table 17, it can be noted that wind effects are significant with respect to tidal elevations. Changes are somewhat more

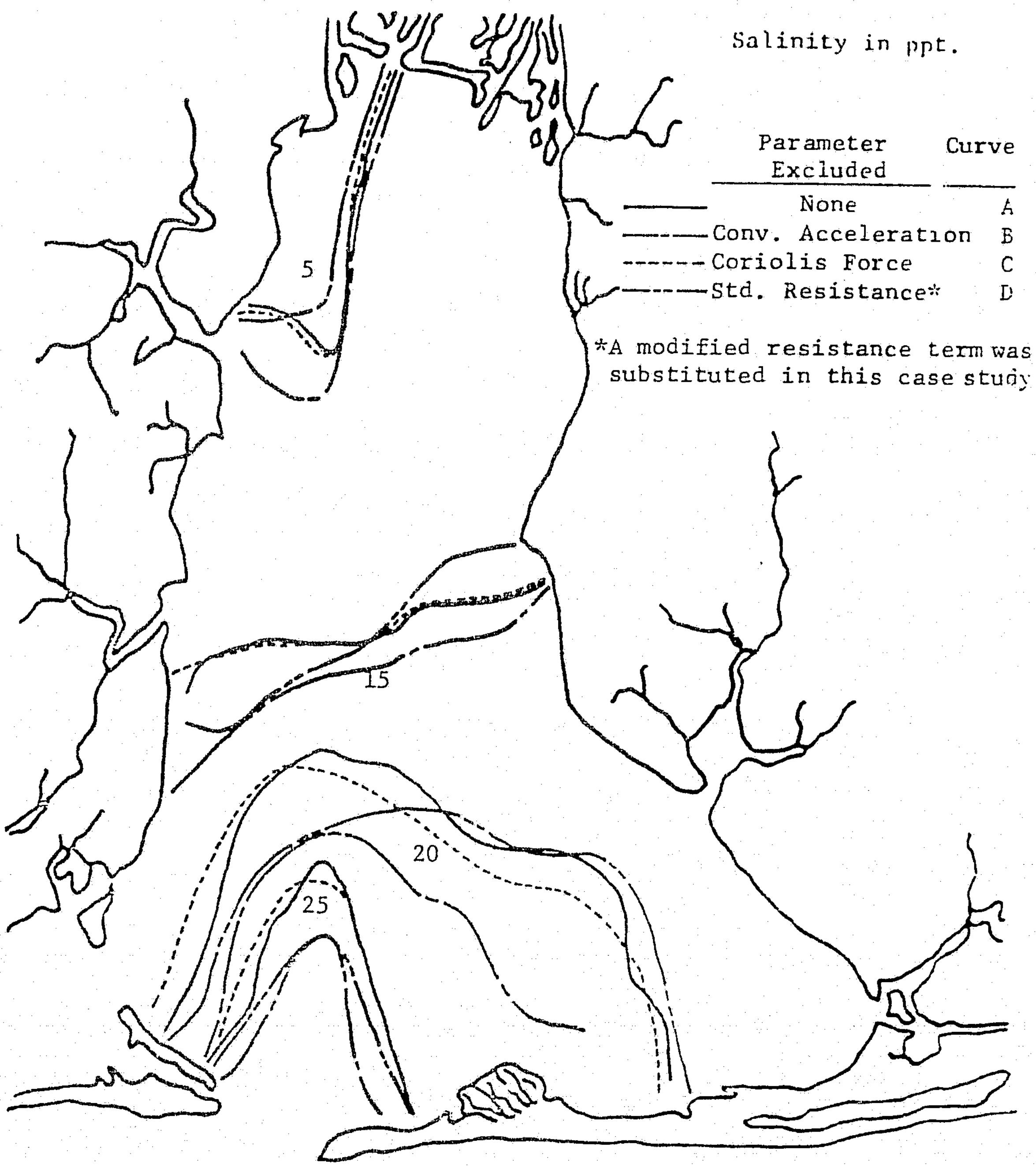


Figure 31. The Influence of Model Parameters on the Salinity Distributions in Mobile Bay for a 44,000 cfs River Flow in Mobile River.

Table 17. Extreme Tidal Elevations (Feet) from Mean Sea Level for High River Flow Conditions (245,000 cfs).

Run Number	13	14	15	16	17	18
Wind Condition						
Speed, knots	0	15	25	0	0	0
Direction	SW	SW	SW	SW	SW	SW
Convective Acceleration	YES	YES	YES	NO	YES	YES
Coriolis Force	YES	YES	YES	YES	NO	YES
Resistance Calculation						
Standard	YES	YES	YES	YES	YES	NO
Modified	NO	NO	NO	NO	NO	YES
State Docks						
High Tide	3.60	3.29	4.28	3.07	3.05	3.07
Low Tide	2.12	2.23	2.84	2.04	2.13	1.93
Point Clear						
High Tide	2.55	2.70	3.33	2.54	2.57	2.54
Low Tide	0.05	0.26	1.09	-0.11	0.08	-0.17
Fowl River						
High Tide	2.58	2.70	3.21	2.57	2.57	2.57
Low Tide	0.14	0.31	1.01	0.00	0.11	-0.09
Bon Secour River						
High Tide	2.47	2.48	2.81	2.43	2.50	2.45
Low Tide	-0.04	0.07	0.47	-0.17	0.00	-0.23

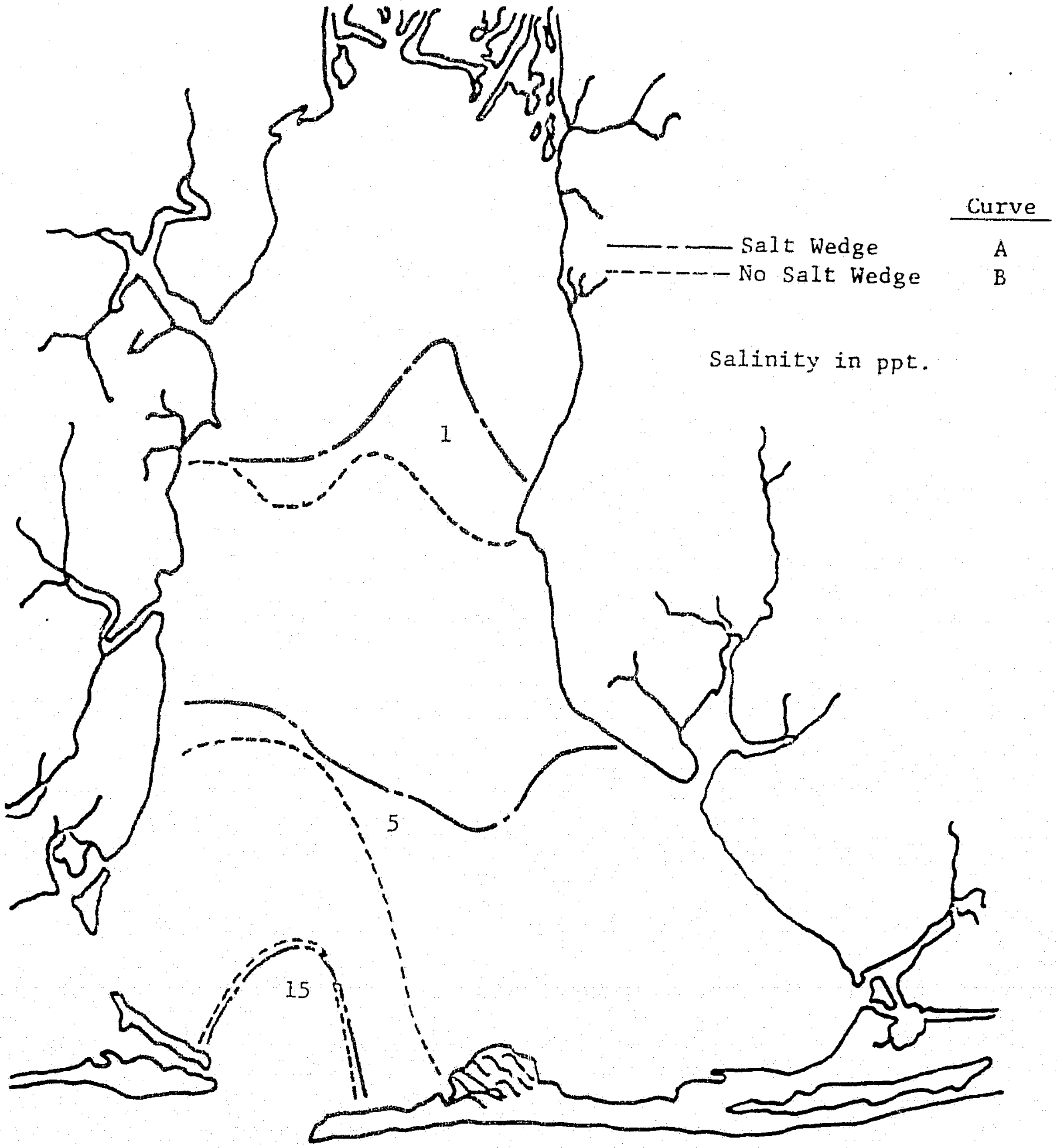


Figure 32. The Influence of a Simulated Salt Wedge (Stratification) Condition on the Salinity Distribution in Mobile Bay for a 245,000 cfs River Flow in Mobile River.

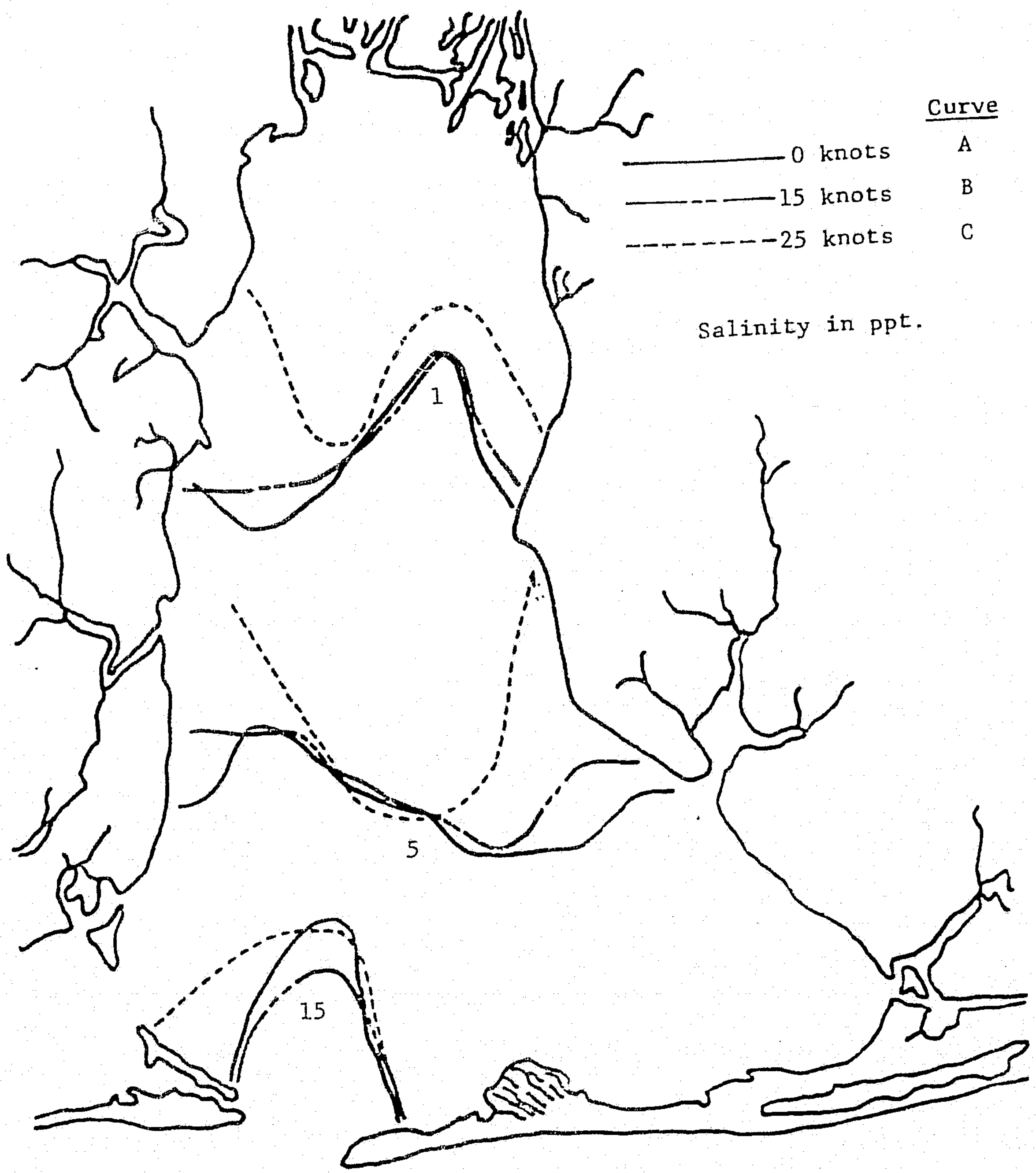


Figure 33. Effect of Southwest Wind Speed on Salinity Distributions in Mobile Bay for a 245,000 cfs River Flow In Mobile River.

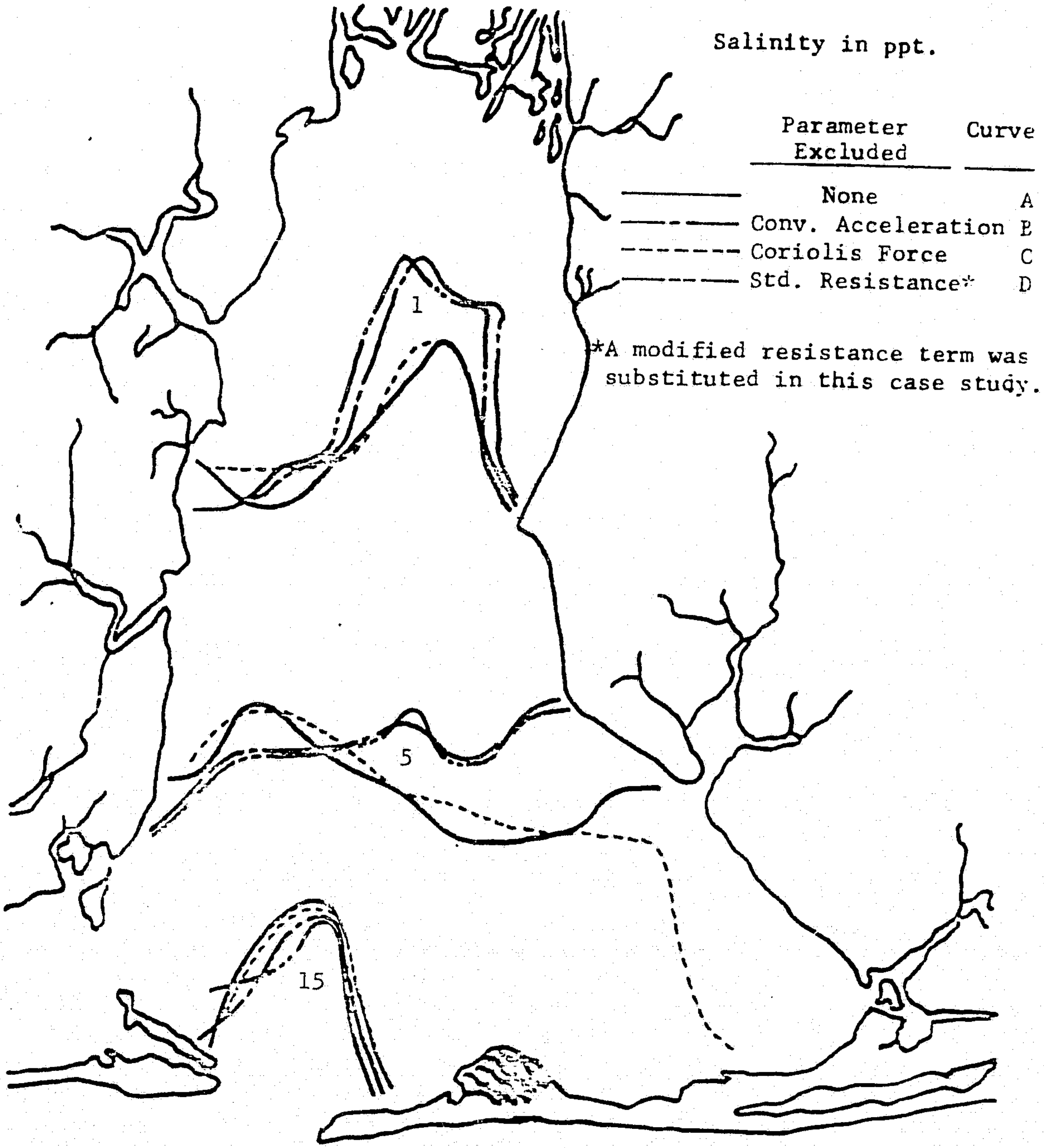


Figure 34. The Influence of Model Parameters on the Salinity Distributions in Mobile Bay for a 245,000 cfs River Flow in Mobile River.

difficult to observe in the figures for State Docks due to the depressed amplitudes resulting from high river flow.

Effects of the salt wedge at low wind conditions (15 knots) may be observed from a comparison of curves A and B in Figure 32. Curves A and B represent the same data with the exception of the salinity wedge which was omitted in curve A. Even though significant data is not available for substatiation, it is believed that the profile shown as curve A is more representative of the actual system under high river flow conditions. This would indicate the need for additional data to effectively use the salt wedge concept in its present form at high fresh water flow conditions. Effects of variable wind may be seen from a comparison of curves B and C with A in Figure 33. Fresh water flows are shifted to the east resulting in an inversion of the salinity curves.

Effects of the convective acceleration and Coriolis force terms on tidal amplitudes are analogous to those observed previously for other fresh water flows as can be noted in Table 17.

Variations in salinity patterns for high river flow may be noted from a comparison of curve A with curve B and C in Figure 34 for convective acceleration and Coriolis force respectively. Without convective acceleration, isohalines near Main Pass are shifted somewhat to the east. Major differences are noted in isohalines for one and five parts per thousand. The major changes resulting from the deletion of the Coriolis force are observed in the isohaline for five parts per thousand as shown in curve C. The area that lies between the isohalines for five and fifteen parts per thousand diminishes by approximately seventeen square miles when the Coriolis force is deleted.

Effects of the modified resistance terms are similar to those previously described for low and medium river flows. Larger quantities of water are allowed to enter and leave the bay and this creates a tidal elevation greater than that observed at high tide and a tidal elevation less than that observed at low tide. It is expected that cross-sectional areas of Main Pass and Cedar Point could be modified slightly and possible slight variations in the depth could be made to compensate for the excess flows observed using the modified resistance terms. Variations in the salinity profile may be observed from a comparison of curve A with curve D in Figure 34. The northern tip of the isohaline for one part per thousand is about four kilometers further north than the results obtained using the modified resistance method. The eastern portion of the five parts per thousand profile is shifted to the north four to six kilometers. In addition, variations are noted in the shape of the profiles adjacent to Main Pass.

<u>Summary of River Flow and Wind Influences</u> - The effect of these system changes on extreme (high and low) tidal elevations at eleven locations (Figure 35) in the bay are shown in Table 18. In each case there is a pronounced influence of wind speed on tidal elevation, especially toward the northern bay. This is caused by the retention of water due to wind

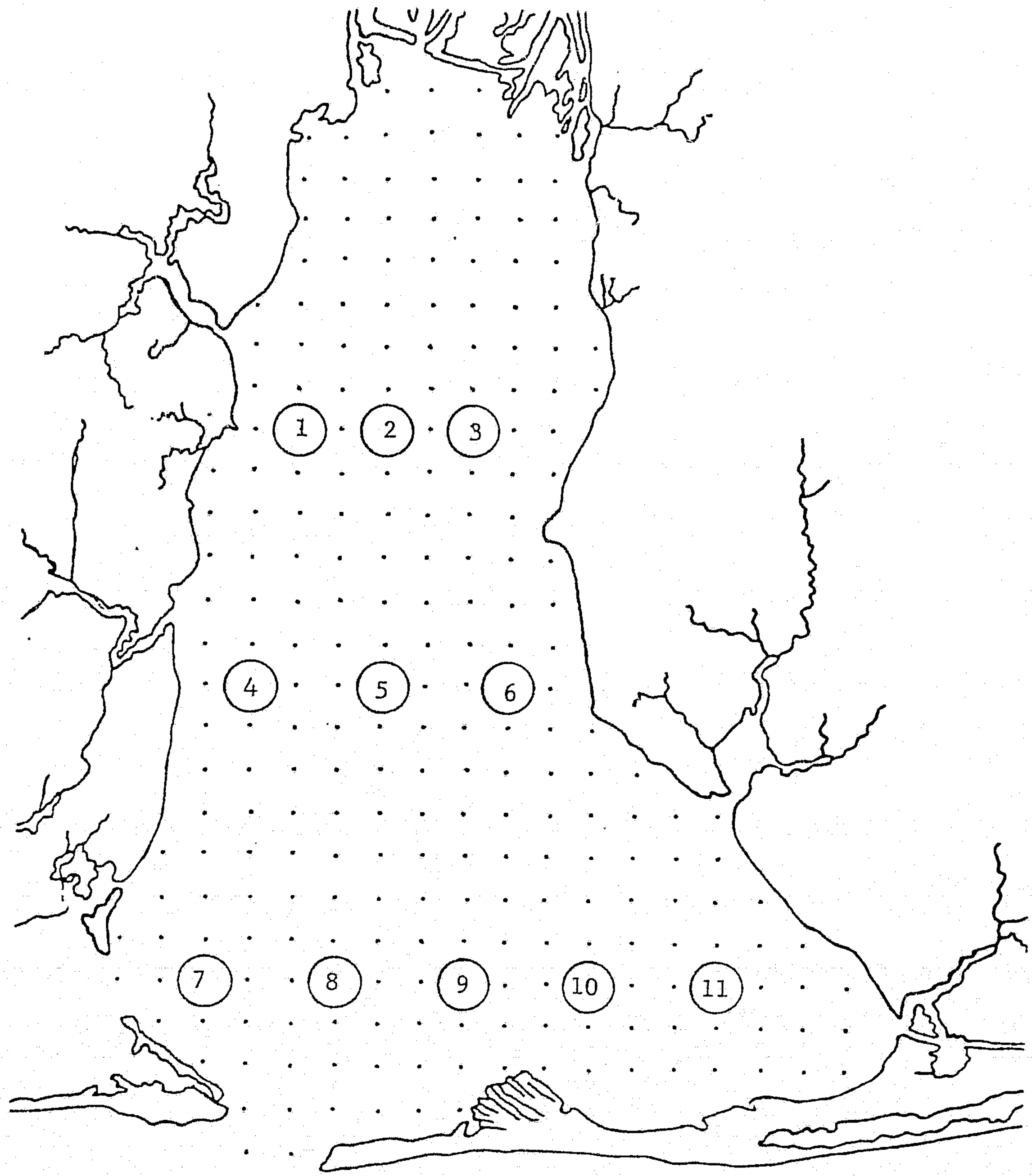


Figure 35. Selected Locations for Comparing the Effects of Wind and River Flow on the Magnitude and Direction of the Net Velocities.

Table 18. Effect of Wind and River Flow on Net Velocities (FPS) and the Direction (Degrees) of Currents.

Wind Velocity (Knots)	River Flow (CFS)	Upper Bay			Middle Bay			Lower Bay				
		1	2	3	4	5	6	7	8	9	10	11
0	12,000	.077 256.5	.018 12.5	.038 308.7	.052 273.3	.077 258.7	.035 198.4	.152 292.5	.207 104.0	.041 278.3	.025 286.3	.013 292.6
15	12,000	.051 248.0	.039 305.7	.072 279.6	.055 272.1	.119 258.4	.034 202.1	.123 255.4	.205 107.3	.047 279.7	.076 279.8	.043 308.5
25	12,000	.048 108.1	.153 286.3	.205 262.4	.068 263.3	.274 259.9	.025 216.9	.512 180.1	.244 117.6	.051 275.6	.176 269.3	.038 61.4
0	44,000	.172 258.6	.075 313.9	.077 288.9	.099 273.5	.125 264.5	.059 254.3	.137 256.9	.170 114.8	.067 252.6	.033 257.7	.016 277.1
15	44,000	.142 256.6	.106 301.1	.118 276.3	.104 272.8	.170 262.2	.061 254.8	.166 227.7	.174 117.0	.075 256.1	.084 269.3	.046 300.0
25	44,000	.042 216.3	.214 288.8	.252 263.4	.113 265.4	.324 258.6	.058 262.1	.595 180.3	.216 125.6	.077 257.2	.186 265.7	.033 61.1
0	245,000	.757 256.9	.466 300.0	.343 272.7	.413 273.9	.438 269.7	.331 281.7	.556 196.6	.186 214.0	.274 232.4	.120 223.0	.048 249.3
15	245,000	.708 256.4	.493 298.0	.382 270.6	.410 272.7	.477 268.4	.326 282.0	.604 193.3	.193 217.0	.277 233.7	.161 239.0	.069 278.4
25	245,000	.466 252.7	.583 291.5	.587 264.6	.392 180.0	.657 263.4	.320 281.9	.912 182.8	.218 218.9	.273 235.7	.261 248.6	.007 180.0

stress conditions and the decrease of bay width from 24 miles in the south to 8 miles in the north.

Similarly, significant variations in tidal elevation are observed at high river flows in the north with a rapid dissapation to nearly normal levels at the mid-bay locations. The influence of these system changes on current direction and speed is likewise discussed in the original study document (4).

The influence of river flow rate on bay salinity is summarized in Figures 28, 30, 33. Suppression of the salinity content of the intruding Gulf waters is observed during high riverine inflow conditions. The bay approaches river-dominant characteristics in the upper one half of the bay when flows exceed ~ 150,000 cfs. Wind changes influence salinity distributions in the bay above 15 knot speeds. Characteristic shifts in fresh water flow patterns can be traced by following salinity profile trends from 0 to 25 knot wind conditions. Downward profiles gradually oscillate as the wind speed approaches 15 knots followed by a complete reversal in the profile at 25 knots. These shifts are directly related to wind stress conditions imposed by the prevailing and constant southwest wind investigated.

Coliform Bacteria Distribution Model

To assess the impact of system variable changes on coliform bacteria distributions in Mobile Bay, a parametric investigation was designed as outlined in Table 19 with corresponding results produced as listed in Table 20. Those parameters studied included water temperature, river flow rate, wind speed and direction and coliform loading at the rivers. Results are expressed as monthly averaged values corresponding to the data used for verification of the model.

<u>River Flow Rates</u> - Increases in the inflow of fresh water from the river systems in the northern bay shift coliform bacteria group counts to the southeastward direction (Figure 36). This is caused by lower retention times needed for the coliform bacteria to die off resulting in higher residual coliform concentrations in all parts of the bay. These results are for constant coliform loading which in most cases does not exist during high river flow conditions. A more realistic way of assessing the effect of changing coliform loads independent of river flow rate is discussed in the next section.

<u>Effect of Varying Coliform Loadings</u> - Cell loading concentration of total coliform at the mouth of a river reflects the pathogenic pollution potential of the river relative to the bay. This concentration is attributed to waste loadings from sources such as municipal, industrial, and rural areas. After periods of heavy rainfall and runoff, the river flow rates stabilize. However, coliform loading along the river course usually peaks and begins decreasing at rates greater than river

Table 19. Data used for Parametric Study runs a to r.

Run	Wind		River Discharge Rates			Temperature	Die-off Rate K
	Speed knots	θ deg.	Mobile River cfs	Dog River cfs	Tensaw River cfs	°F	day^{-1}
a	0	-	24,000	2,000	20,000	78.1	0.72
b	15	225	"	"	"	"	"
c	25	225	"	"	"	"	"
d	15	90	"	"	"	"	"
e	25	90	"	"	"	"	"
f	15	315	"	"	"	"	"
g	25	315	"	"	"	"	"
h	0	-	7,000	500	5,000	84.2	0.90
i	15	225	"	"	"	"	"
j	25	225	"	"	"	"	"
k	0	-	145,000	5,000	100,000	67.9	0.50
l	15	225	"	"	"	"	"
m	25	225	"	"	"	"	"
n	7.9	225	10,000	1,000	9,250	78.1	0.72
o	"	"	40,000	4,000	37,000	"	"
p	"	"	20,000	2,000	18,500	"	"
q	"	"	"	"	"	85.8	0.94
r	"	"	"	"	"	68.1	0.50

Table 20. List of Figures for Parametric Study Comparisons.

Figure	comparison among runs	indicating the effect of variation of	at constant
38	p q r	temperature	river flow rates and wind
36	n o p	river flow rate	wind and temperature
39	a b c	speed of wind from SW	medium river flow
40	a d e	speed of wind from N	medium river flow
41	a f g	speed of wind from SE	medium river flow
42	h i j	speed of wind from SW	low river flow
43	k l m	speed of wind from SW	high river flow
44	a b d f	direction of wind at 15 knots	medium river flow
45	a c e g	direction of wind at 25 knots	medium river flow

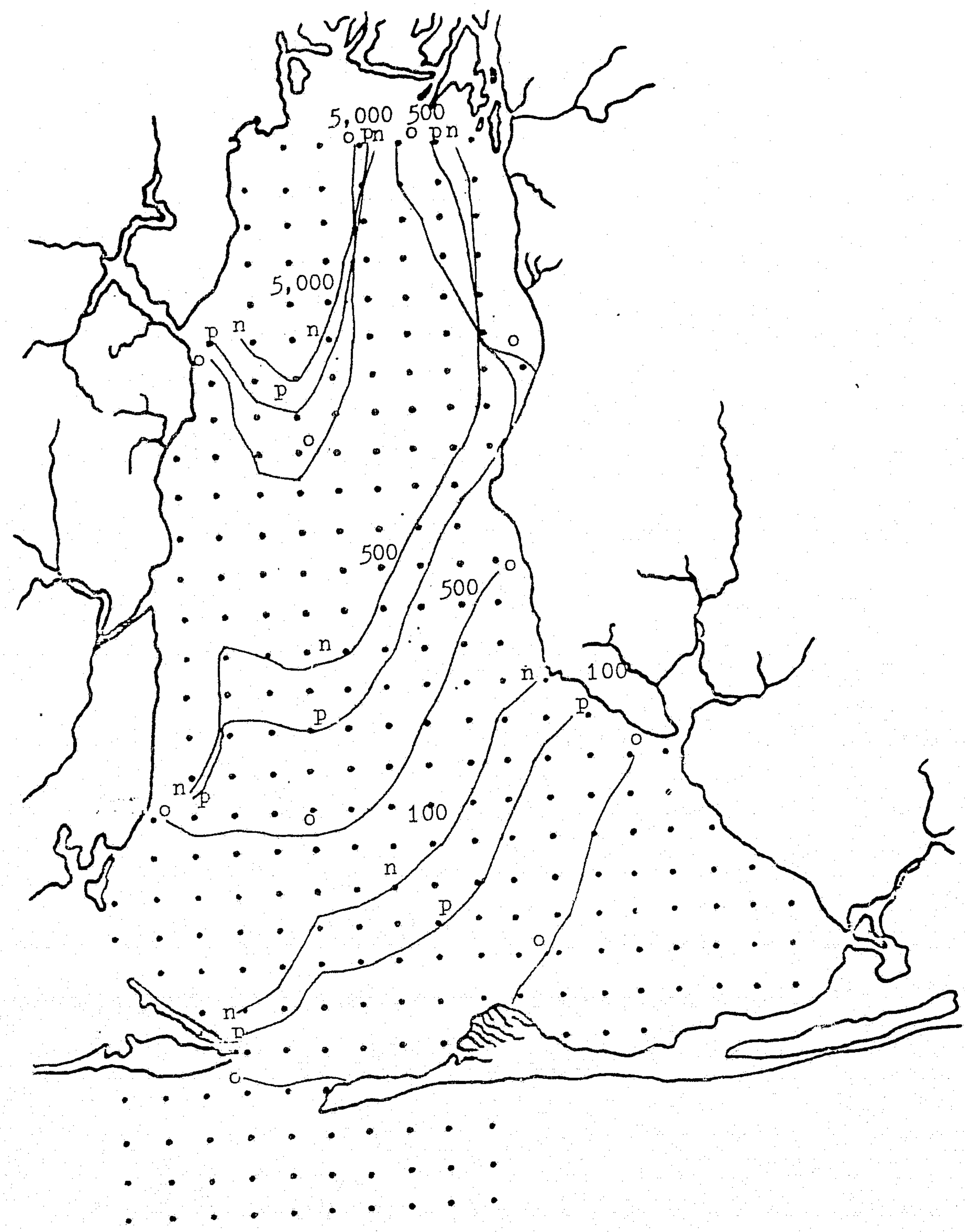


Figure 36. Total Coliform Concentration Profiles from Runs n, o, and p; Displacements of Profiles due to Variations of River Flow Rates.

flow decreases. In this discussion river flow rates, wind conditions, and temperature are held constant. Other parameters were set at values listed in Table 21. The only changes made are on the loading concentrations of total coliform bacteria at the mouths of Mobile River and Dog River. The resulting total coliform concentration profiles are shown in Figure 37. Comparisons are made at two concentration levels, i.e. 70 and 1000 MPN/100 ml. Each of the shifts of the coliform concentration profile is in the order of 2 grid widths (4 km). It is noted that the 70 MPN/100 ml contour shifts as many as 6 grid widths from one extreme to the other as 7/8 of the original total coliform bacteria is removed or reduced. These changes in total coliform loading are also more representative of conditions that might be achievable for varying degrees of treatment of municipal and industrial waste sources.

Temperature - Figure 38 shows the effects of changing temperatures on total coliform distribution. The shifts of the 100 and the 500 MPN/100 ml total coliform concentration isolines are in the order of 2 to 4 grid widths (4 to 8 km.) from run to run, which can seriously affect the shellfish harvesting activities in the bay (10,11), especially in the Bon Secour areas. This simulates what can happen to the coliform distribution in case of sharp temperature variations when all the other system variables, i.e. river flow rates, wind conditions, and waste loadings, remain unchanged. The reason for such pronounced shifts of coliform concentration profiles is the change in dieoff rate constant, K_r, caused by temperature variation. When water temperature in the bay is higher, total coliform bacteria dissipate at a higher rate, and the coliform concentration in the bay becomes lower. When the water temperature is lower, K_r is smaller, the total coliform bacteria dieoff at a lower rate, and the coliform concentration in the bay becomes higher. This effect also partly accounts for observed seasonal variation of total coliform concentration within Mobile Bay (12).

Wind Speed and Direction - Three wind speeds (0, 15, 25 knots) and three wind directions (north, southeast, southwest) were investigated relative to the effects produced in coliform bacteria distributions in the bay. These results are shown in Figures 39-45. In all cases wind influence showed the least impact on distribution patterns. This is due in part to the manner in which the patterns are estimated by the model (depth averaged) and also in part to the time frame over which calibration and verification events were achieved (monthly averaged data). It is obvious that wind induced surface flows and mixing can influence bacteria distribution within the bay. However, until a stronger data base becomes available, one may only speculate as to the extent wind direction and speed alters the distribution patterns. Current model results are severely restricted in this area of the investigation.

Table 21. Data used for Parametric Runs p, s, t, u.

Run	River Flow Rates, Wind Conditions, and Temperature	Loading Concentration (MPN/100ml) at		
		Mobile River Mouth	Dog River Mouth	Other Location
p	Same as run p in Table 37	40,000	1,800	Same as those of May, 1962 in table
s	"	20,000	900	"
t	"	10,000	450	"
u	"	5,000	225	"

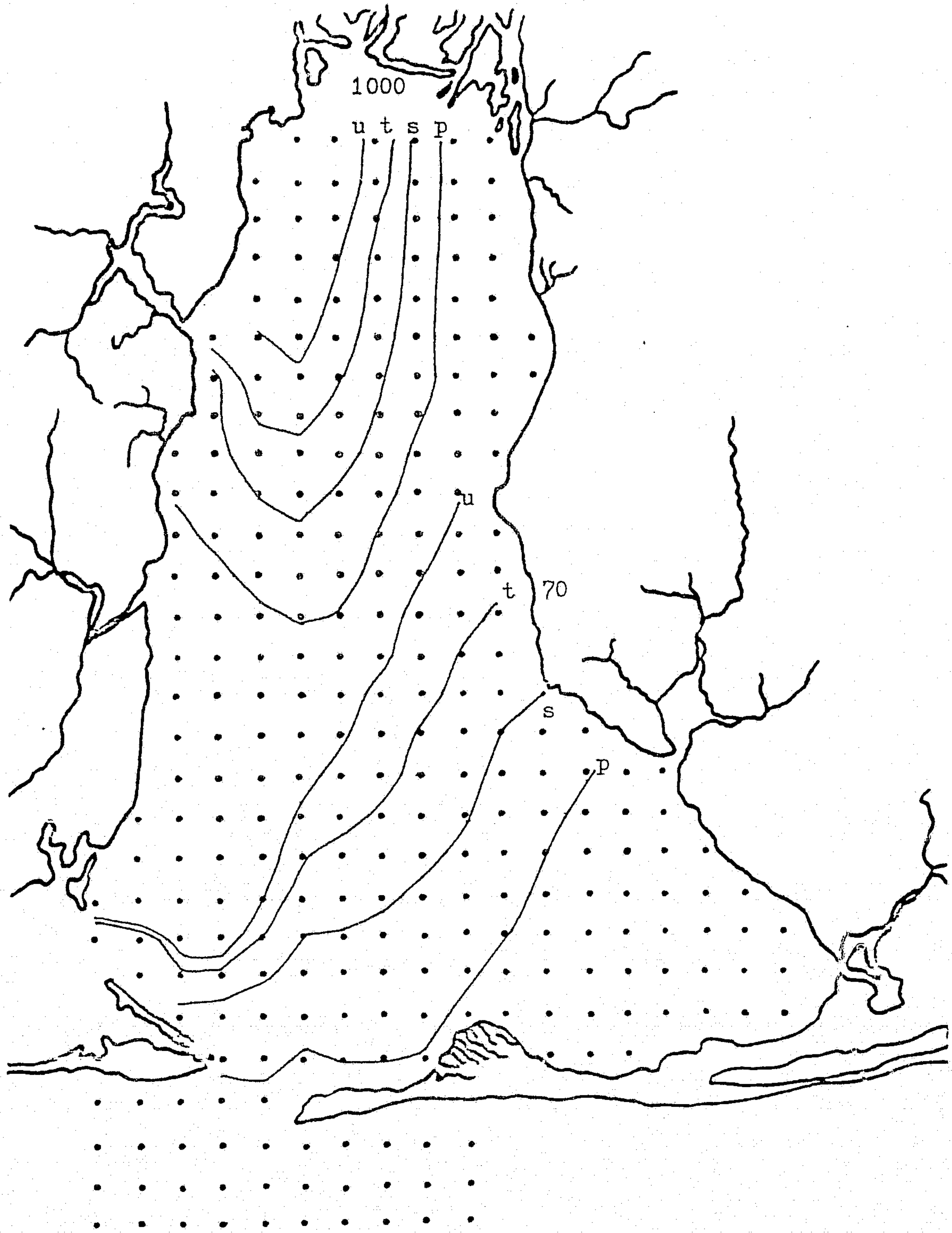


Figure 37. Total Coliform Concentration Profiles from Runs p, s, t, and u;Displacements due to Changes in Treatment Levels.

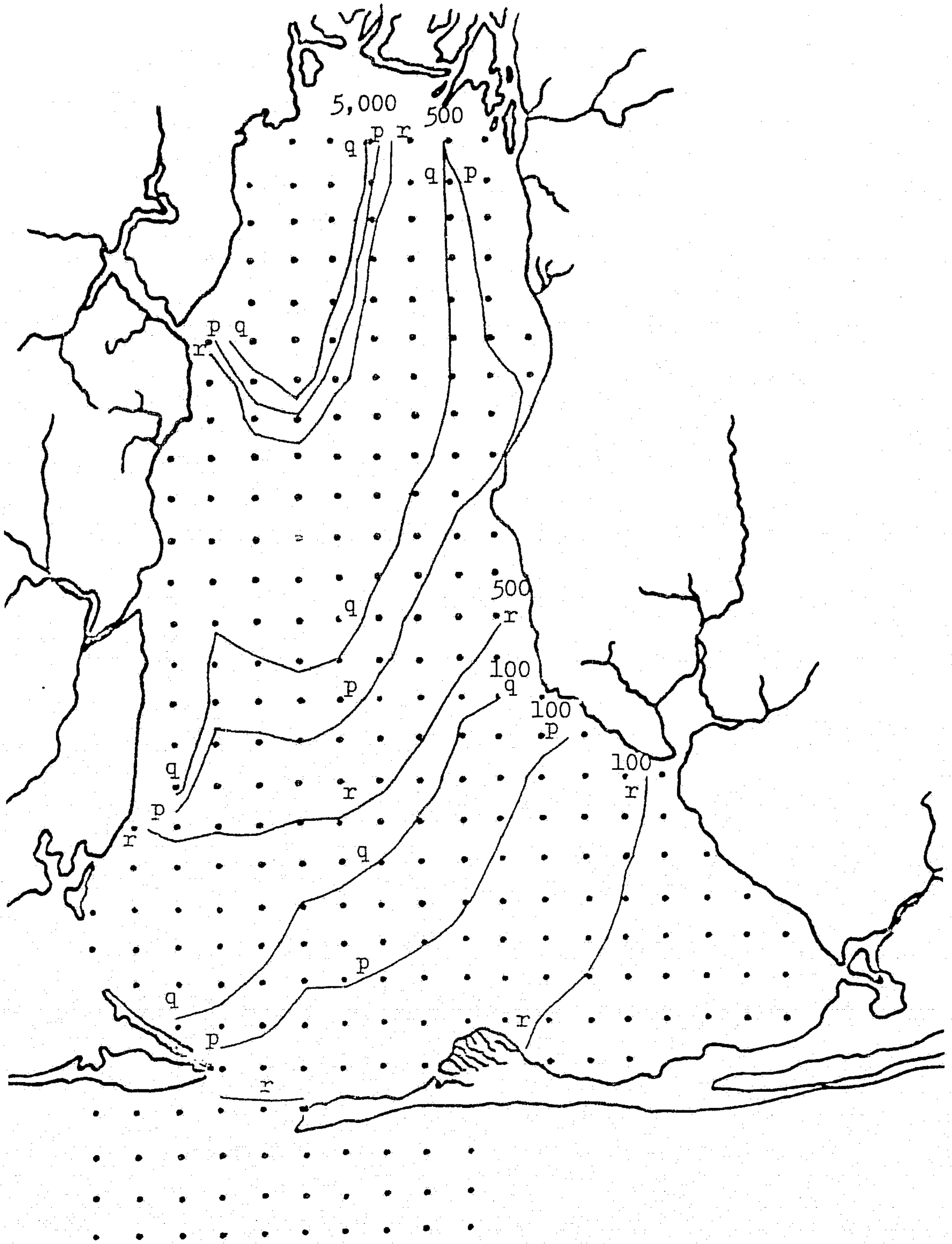


Figure 38. Total Coliform Concentration Profiles from Runs p, q, and r; Displacements of Profiles due to Variations of Temperature.

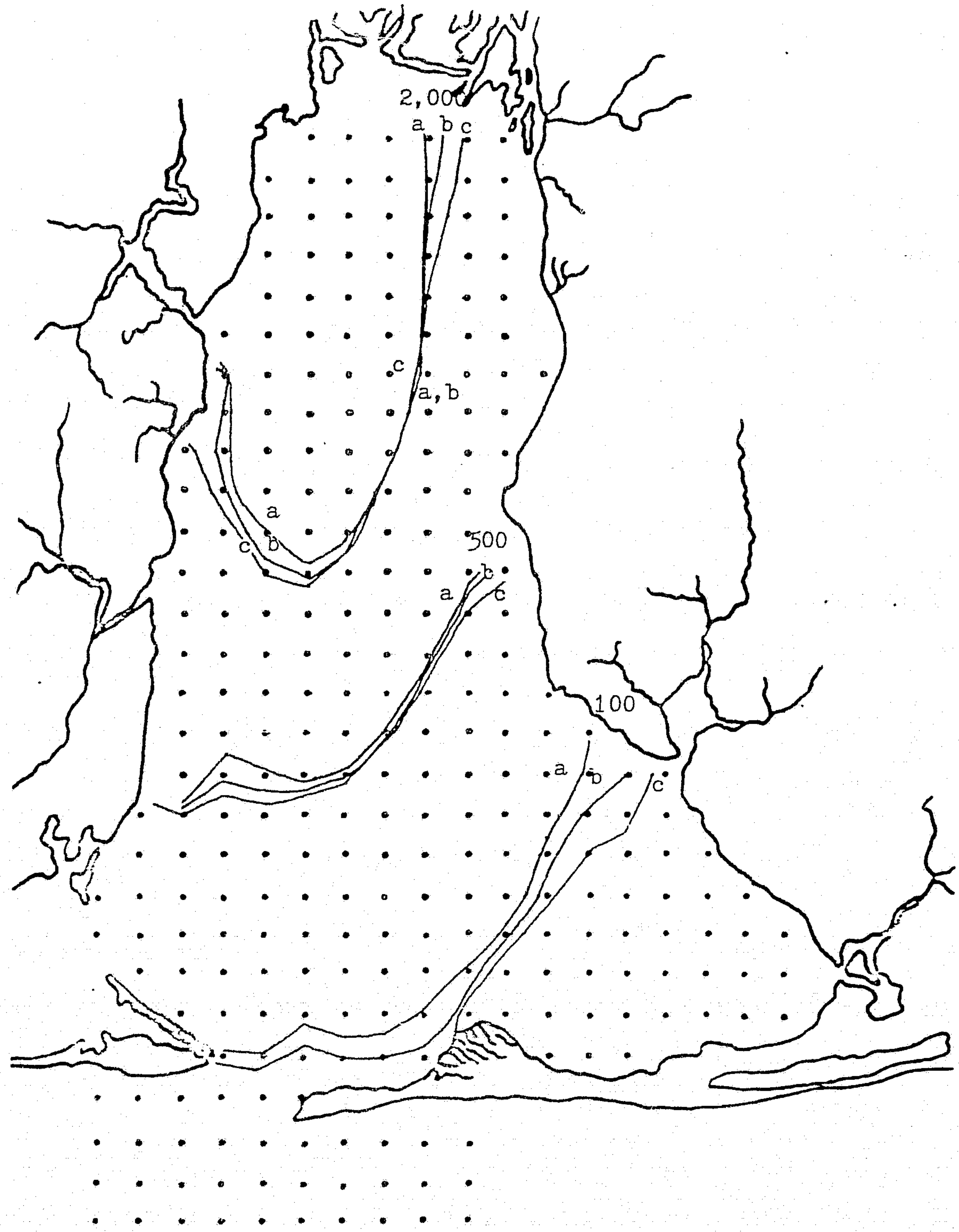


Figure 39. Total Coliform Concentration Profiles from Runs a, b, and c, Medium River Flow Rates; Wind from SW at 0, 15, and 25 Knots.

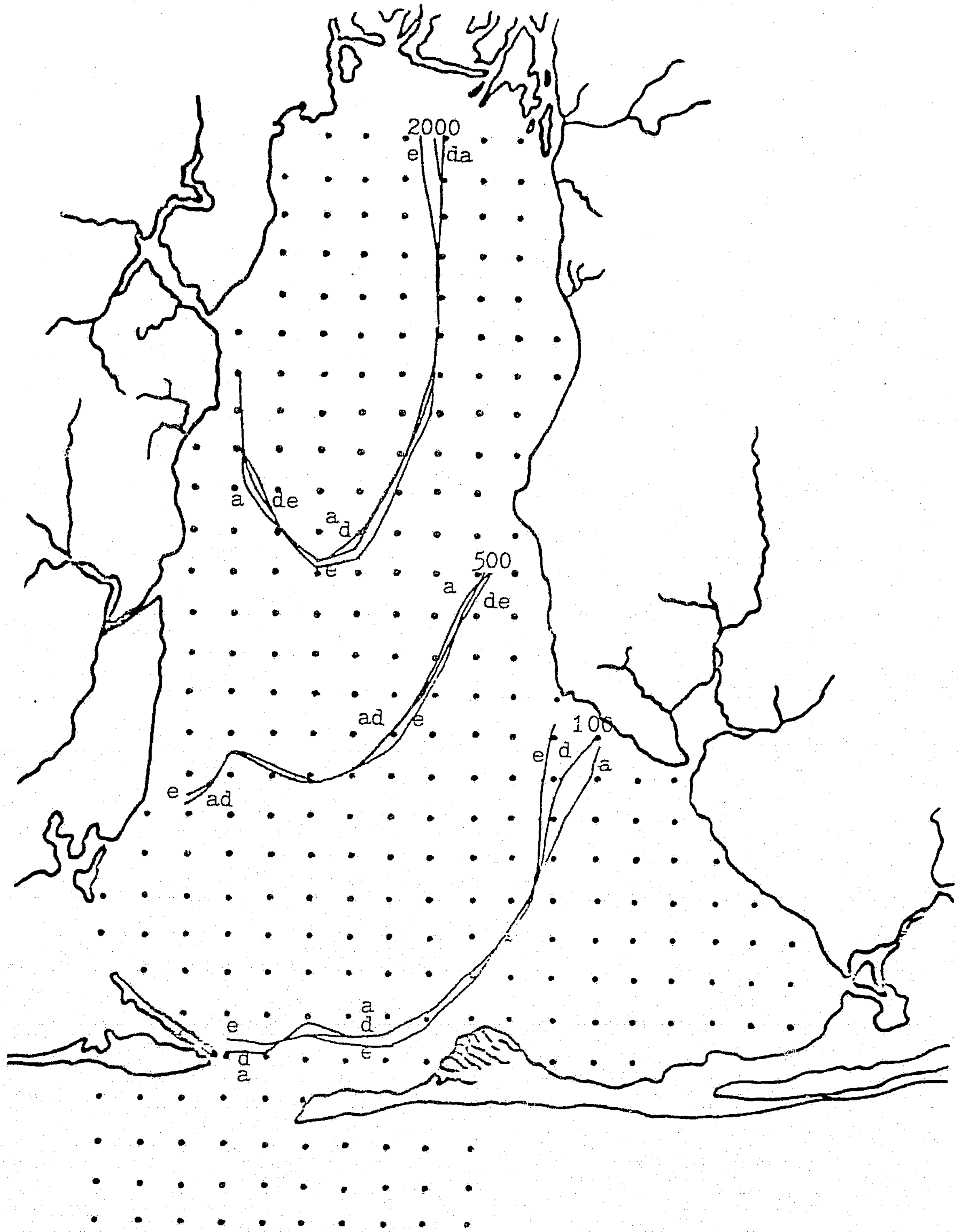


Figure 40. Total Coliform Concentration Profiles from Runs a, d, and e for Medium River Flow Rates; Wind from N at 0, 15 and 25 Knots.

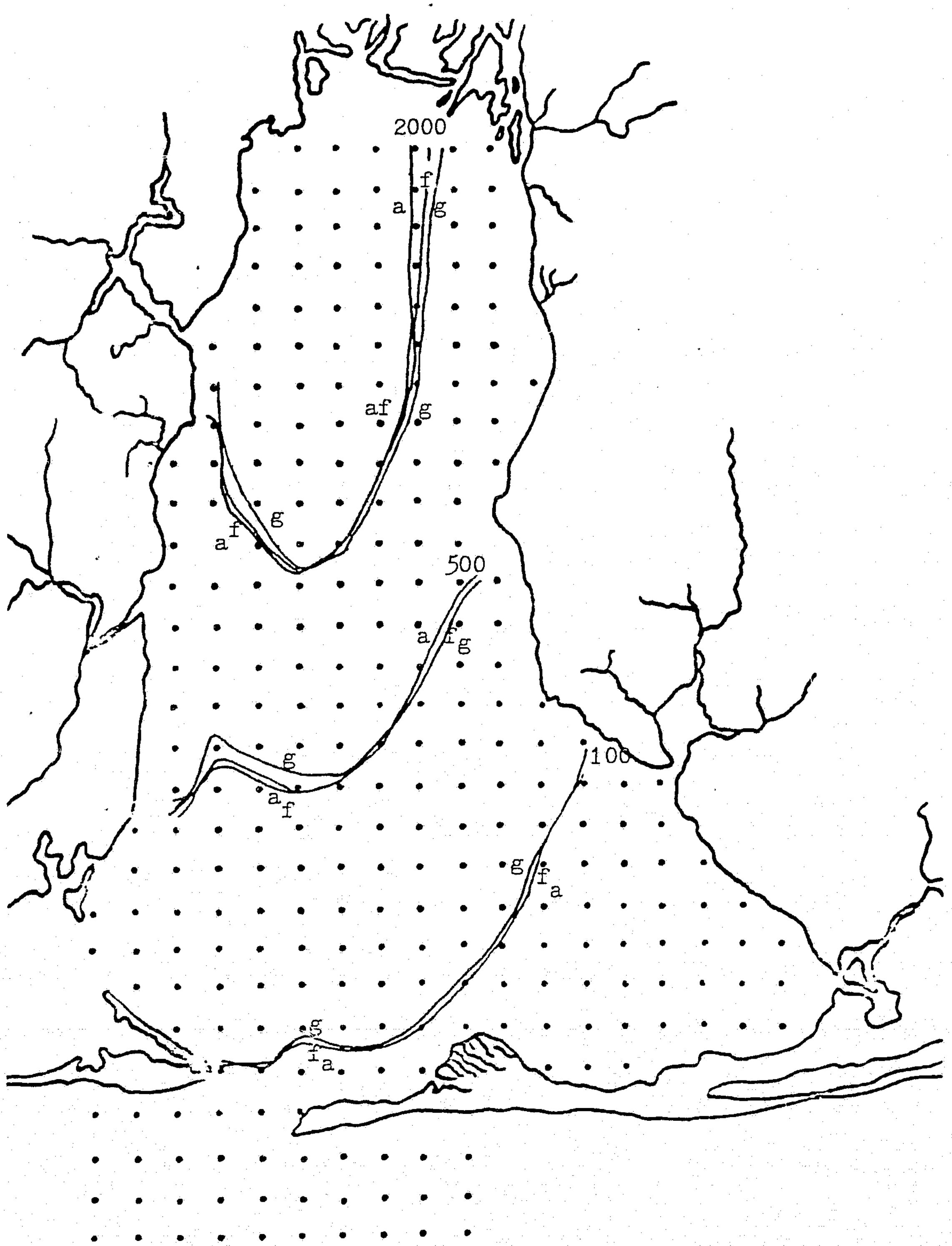


Figure 41. Total Coliform Concentration Profiles from Runs a, f, and g for Medium River Flow Rates; Wind from SE at 0, 15, and 25 Knots.

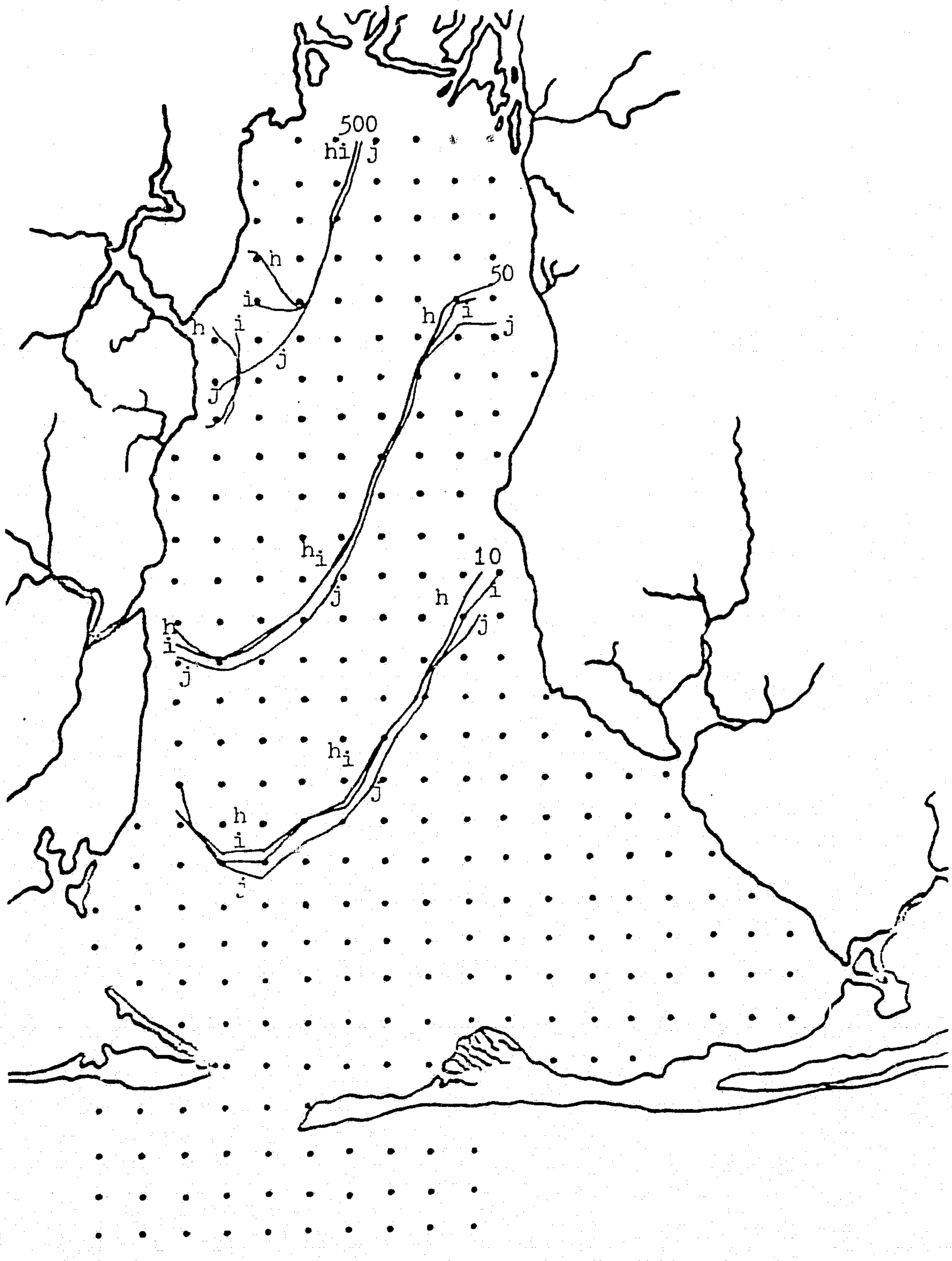


Figure 42. Total Coliform Concentration Profiles from Runs h, i, and j for Low River Flow Rates; Wind from SW at 0, 15, and 25 Knots.

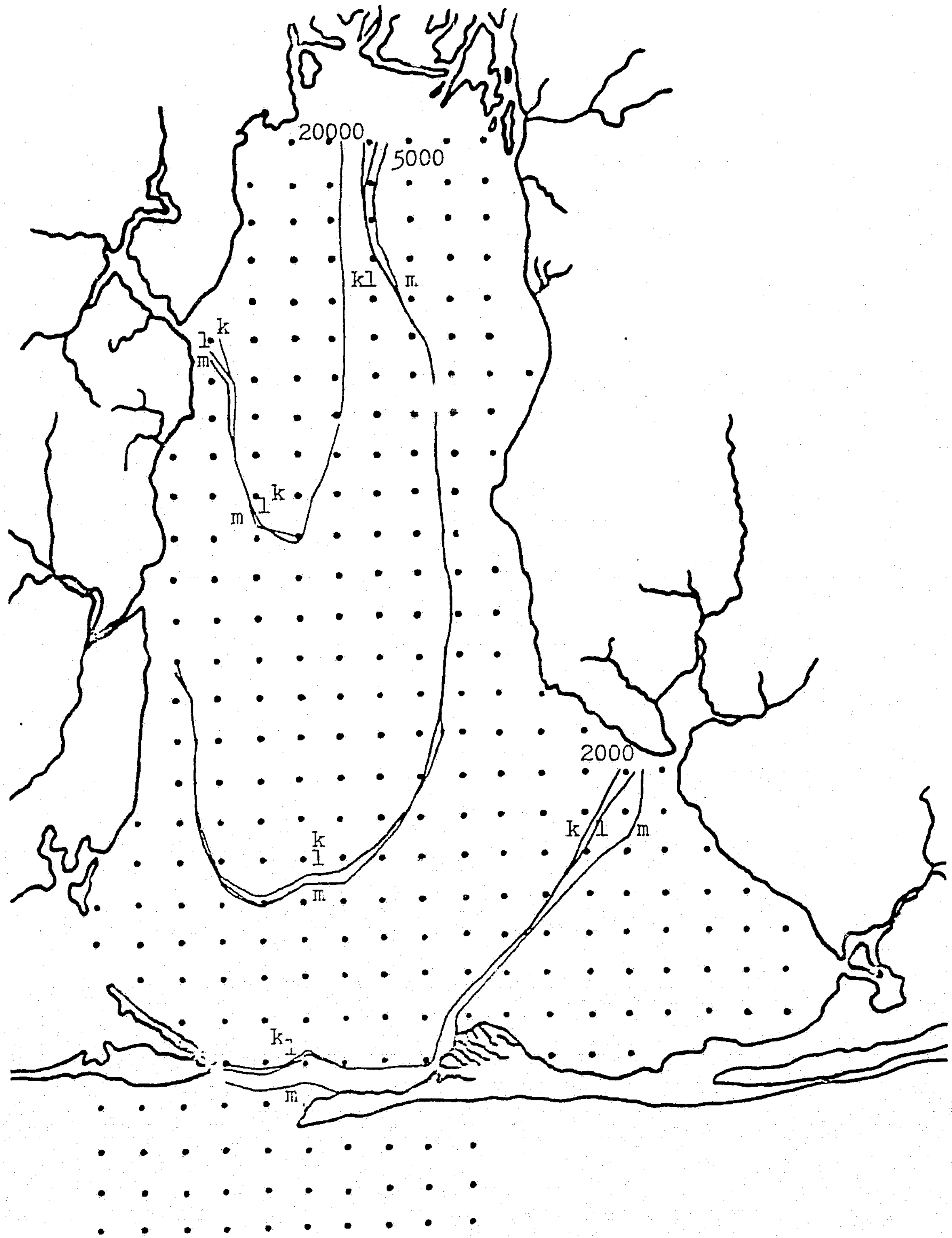


Figure 43. Total Coliform Concentration Profiles from Runs k, l, and m for High River Flow Rates; Wind from SW at 0, 15, and 25 Knots.

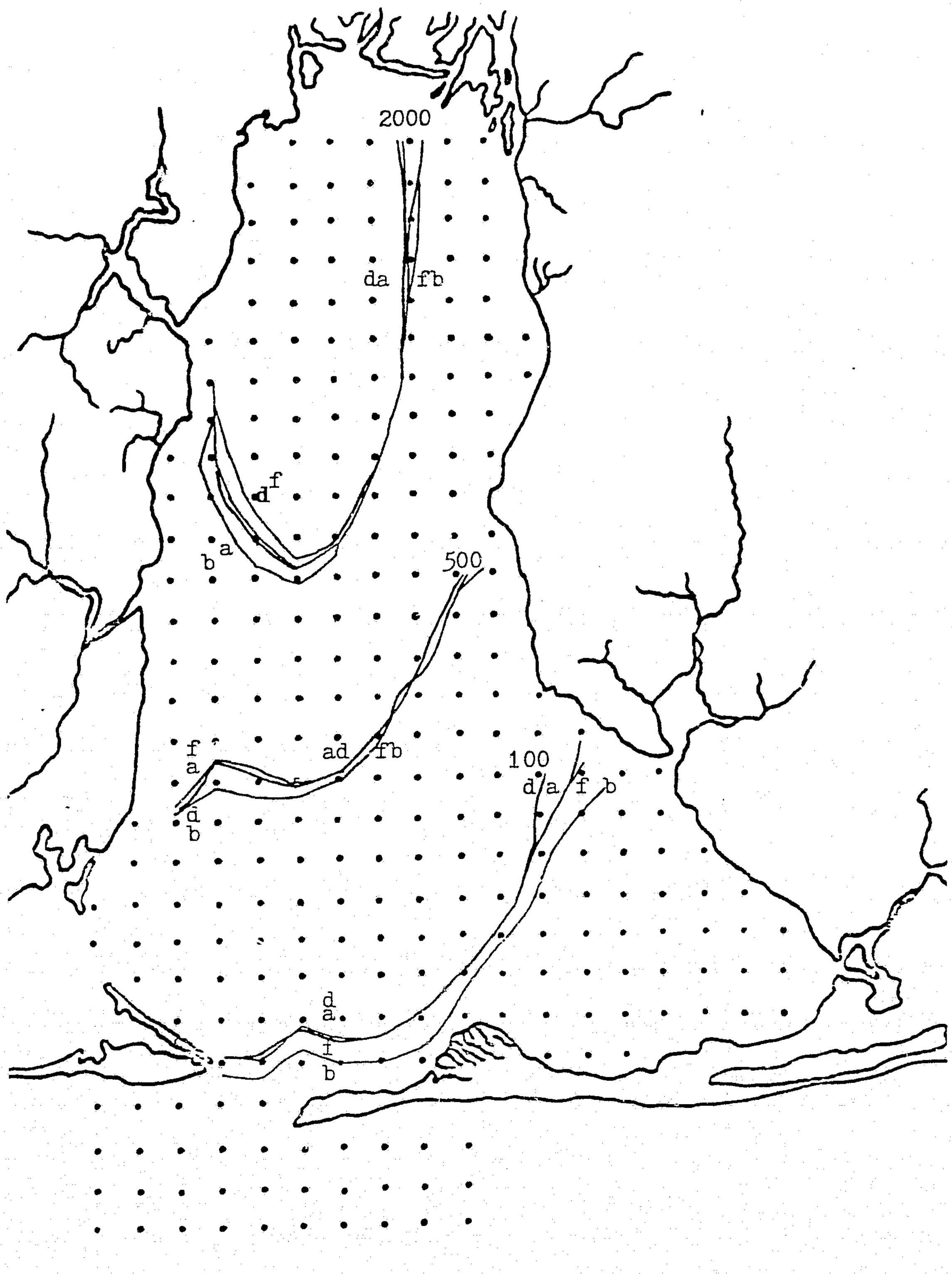


Figure 44. Total Coliform Concentration Profiles from Runs a, d, f, and b for Medium River Flow Rates; Wind Constantly at 15 Knots from SW, N, and SE.

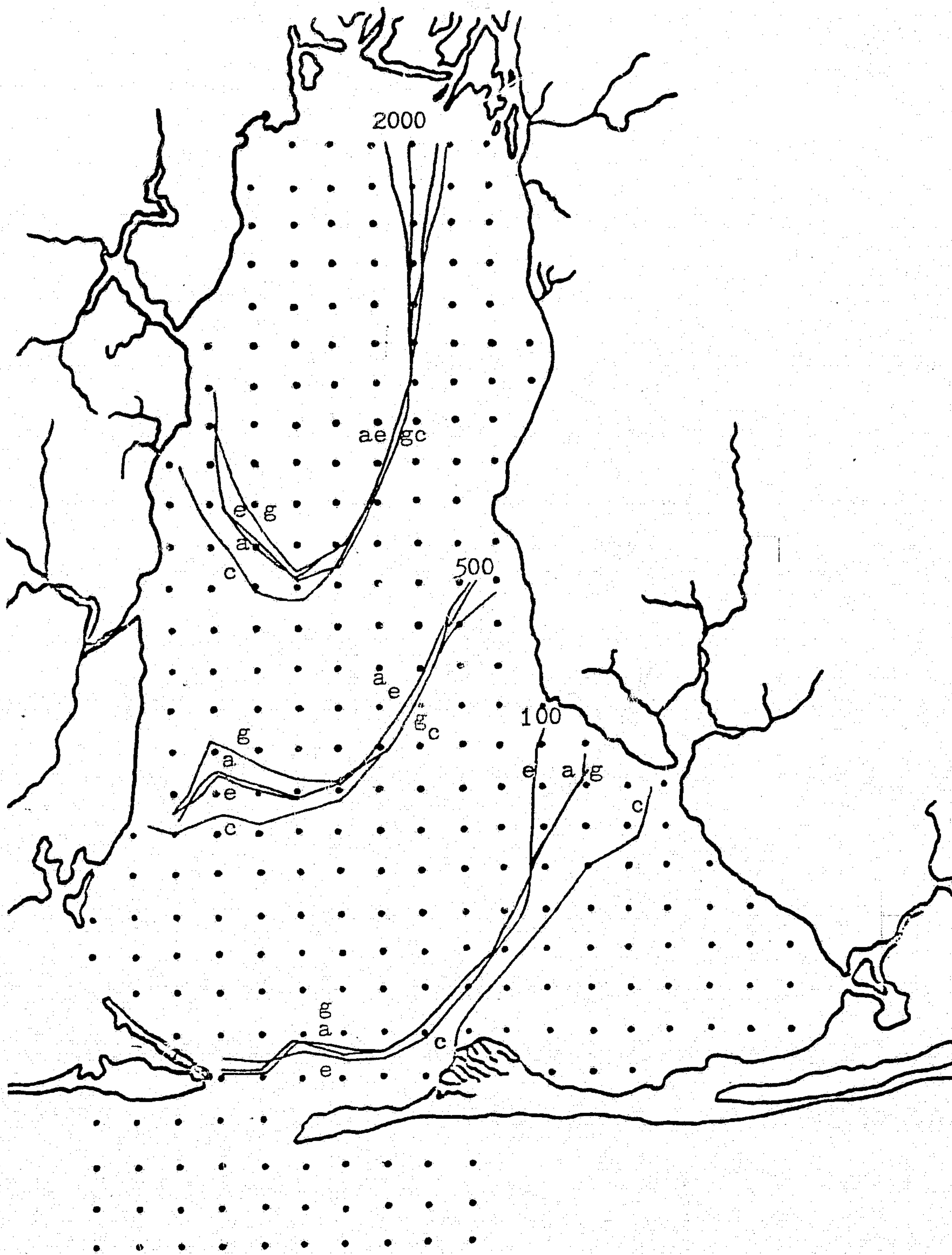


Figure 45. Total Coliform Concentration Profiles from Runs a, c, e, and g for Medium River Flow Rates; Wind Constantly at 25 Knots from SW, N, and SE.

Sediment Distribution Models

Of the several models formulated for Mobile Bay, the sediment distribution models were the most difficult because of the rather sparse data available for this phase of the study. As a result several different methods were developed to take advantage of the available data. These methods included correlative techniques using bathymetry for seasonal or longer periods of time, remote sensing photographic correlative techniques for within tidal and tidal cycle conditions, and more rigorous methods for predicting sediment discharge patterns from dredges for subsystems during tidal periods. Each of these methods and the corresponding results will be discussed in the following sections.

The Effect of Seasonal Variations on Sediment Transport in Mobile Bay - Just as there are settling and scouring events within tidal cycles, there also exist seasonal variations which influence the sediment transportation and deposition characteristics within the bay. The effect of these seasonal events are studied by considering the hydrodynamic behavior of the bay using mathematical modeling methods. In particular, for the purpose of this report, correlation of the hydrodynamic and sediment transport behavior is made using a tidal cycle average current generated for seasonal average flow conditions. This technique is a convenient method of lumping variables which are difficult to interpret and impossible to obtain over long term periods. The method provides a rapid assessment of those regions more susceptible to high transport and/or deposition of sediment. For Mobile Bay, a value of 0.2 ft/sec correlates well with observed long term sediment transportation and deposition trends (i.e. a value $<$ 0.2 ft/sec indicates a region of low transportation; a value $>$ 0.2 ft/sec indicates a region of high transportation). Areas which have a high transportation potential regardless of river flow rate are indicated by the closed regions (Figure 46). These include the Bay areas adjacent to passes and waters near the Mobile and Tensaw Rivers in the north

The open areas represent regions of low sediment transportation. These areas include the head waters between the Mobile and Tensaw Rivers, the Bon Secour Bay area and regions along the western shoreline. The seasonal variations can be observed by following the progression of the high transportation potential areas from high to low river flow conditions. It is likely that materials deposited during low river flow conditions become resuspended during high river flow periods. This phenomenon can be traced using the hydrodynamic and material transport model for the bay. Included in this method of analysis are allowances for turbulence as estimated by local dispersion coefficients.

The Impact of Channelization on Long Term Sediment Transport in the Bay - In order to assess the possible long term impact that the Mobile ship channel has had on bay circulation and sediment transportation patterns, the hydrodynamic model was run under two conditions. The first set of conditions was derived from the 1847-1851 bay contour diagram from which

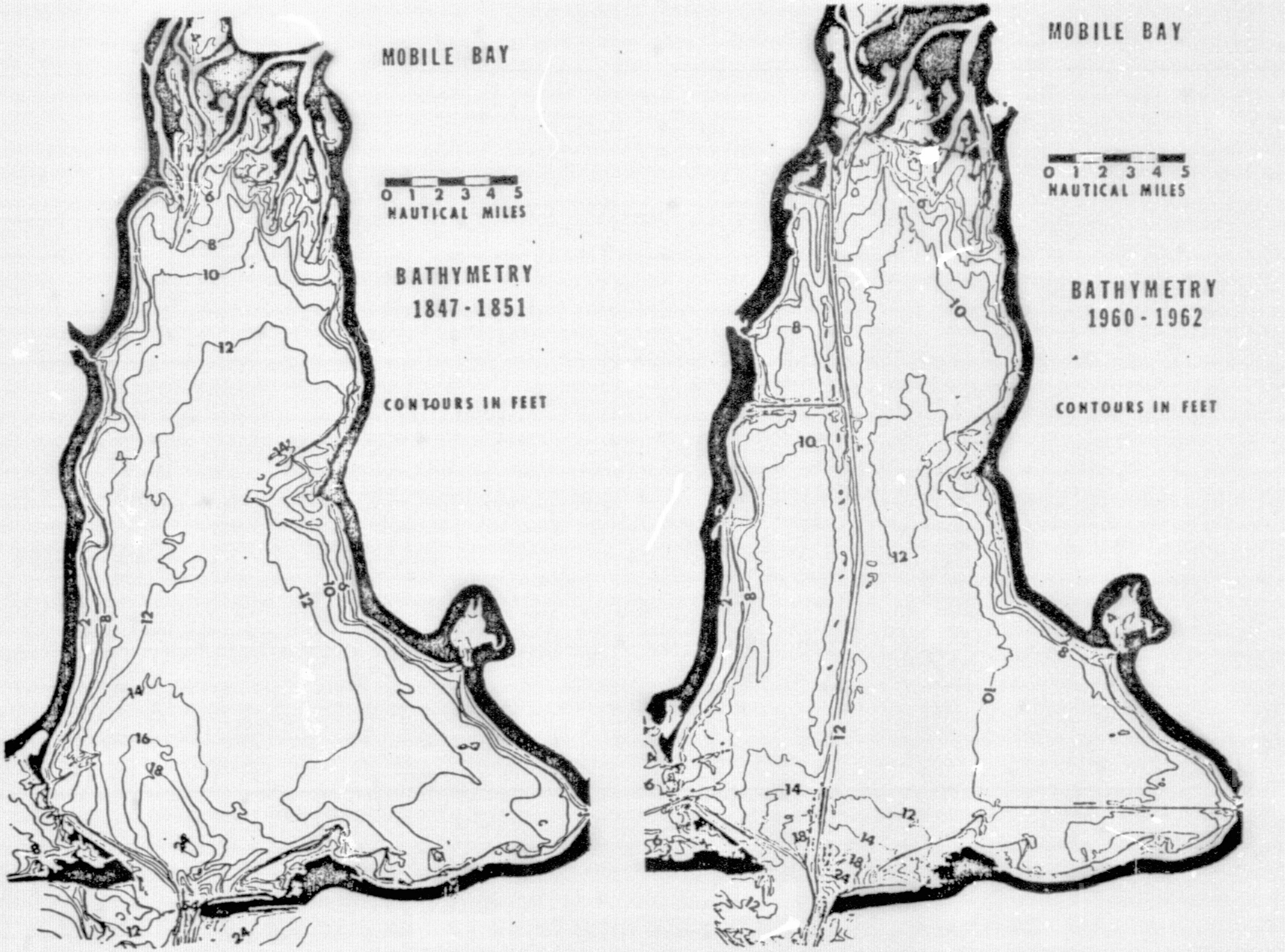


Figure 46. Bathymetric Data for Mobile Bay, Alabama; 1847-1851 and 1960-1962.

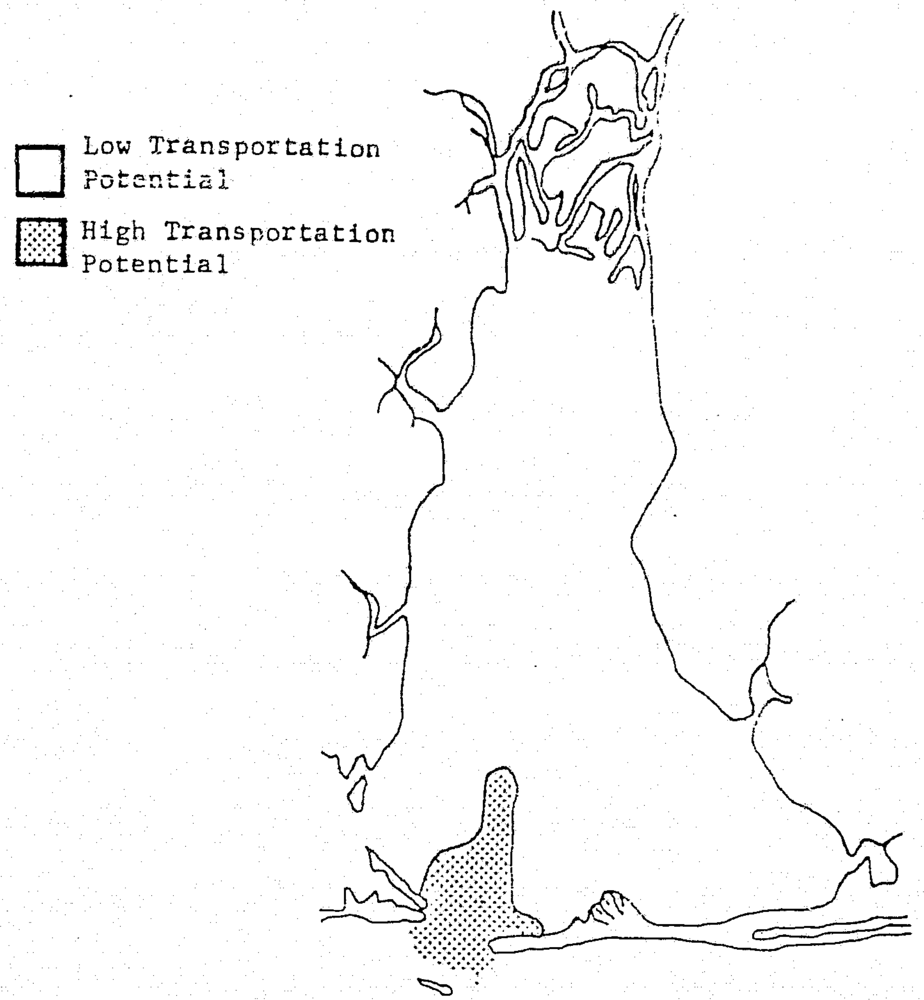


Figure 46a. Schematic Diagram Illustrating the Areas of High Transportation Potential at Low River Flow Conditions.

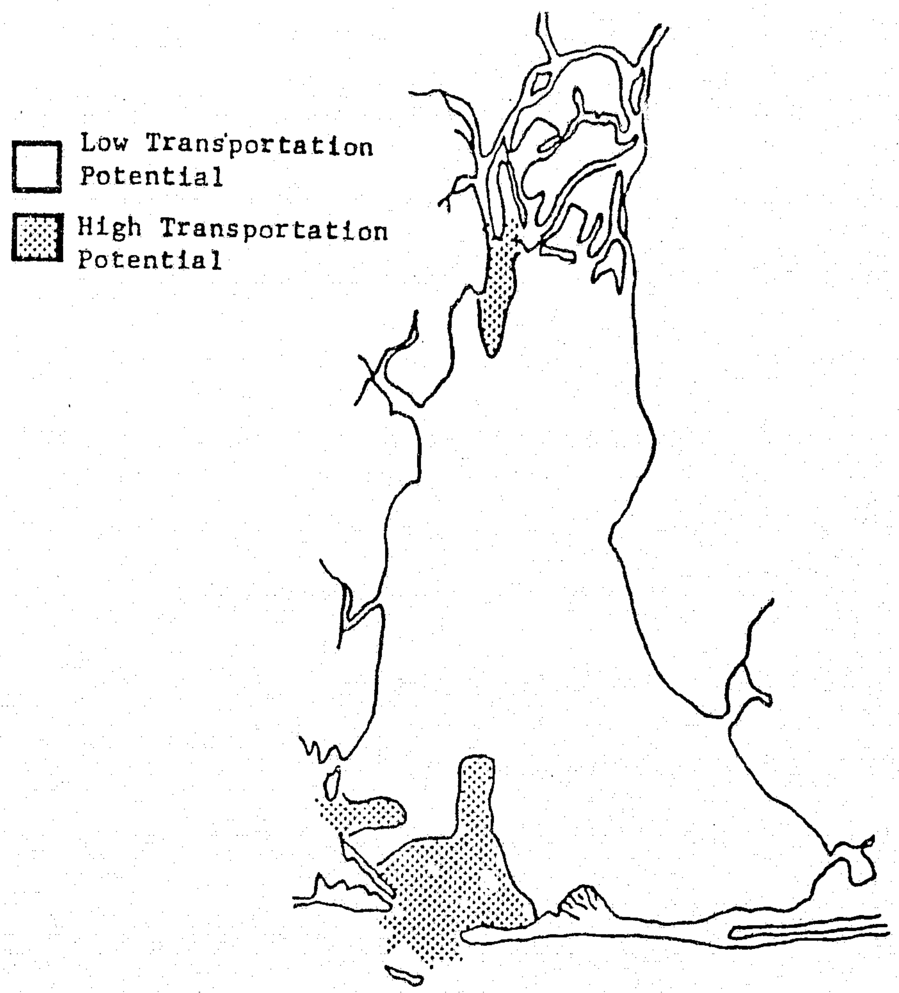


Figure 46b. Schematic Diagram Illustrating the Areas of High Transportation Potential for Medium River Flow Conditions.

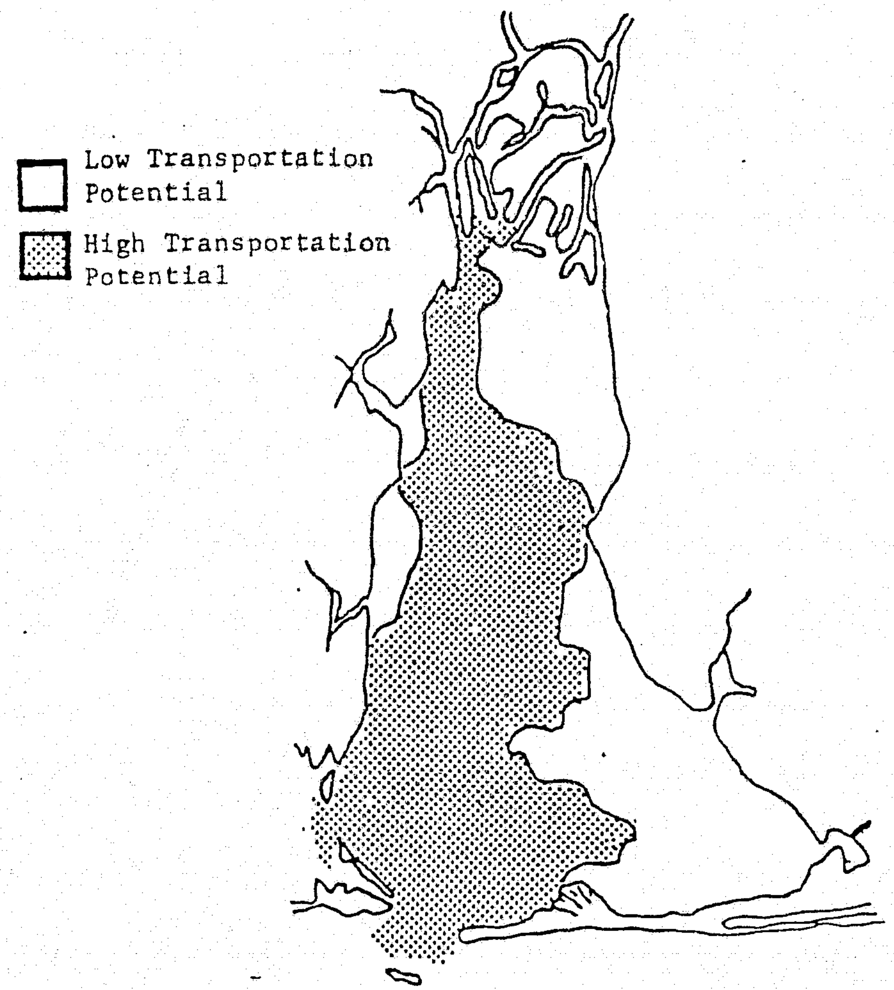


Figure 46c. Schematic Diagram Illustrating the Areas of High Transportation Potential for High River Flow Conditions.

bay depths were used as input to the model (2). The second set of conditions were those including the ship channel in which bay depths and model parameters were adjusted to simulate this modification to the natural system. Both cases were run for a river flow rate of 125,000 cu.ft./sec. Transportation patterns were again determined using the tidal cycle average velocity criteria discussed earlier (Figure 47). A more even transportation pattern is observed over the lower two-thirds of the bay for conditions in which the ship channel is excluded. This condition can be explained by the higher volumetric throughput that occurs as a result of channelization along the west-central bay. A comparison of these results with deposition maps for the periods 1852-1920 and 1920-1973 prepared from bathymetric data supports the general patterns projected by the hydrodynamic model (Figure 48).

<u>Within Tidal Cycle Variations in Mobile Bay Sediment Transport</u> - Short term variations in sediment transportation patterns within the bay are of two varieties: man-made sediment disturbances resulting from maintenance dredging activities, and, naturally, occurring sediment disturbances caused by high river flow rates, runoff and wind conditions. The latter cases are of particular interest in that it provides a means of interacting the hydrodynamic model with satellite and high altitude photographic data (remotely sensed) obtained during high sediment load conditions.

<u>Sediment Transportation Resulting from Maintenance Dredging</u> - Disturbances to the bay system resulting from maintenance dredging activities in areas adjacent to the Mobile ship channel account for the relocation of approximately 2.7 x 10^8 cubic feet of sediment. Hence, it becomes important to assess the impact that these dredged materials have on bay sediment transport and resettling behavior and the areas affected.

Such an analysis was made using the hydrodynamic model of the bay as a source of current direction and speed, and dispersion coefficient data as a function of tidal state. Subsequently, the material transport model was used for a subsystem defined by the location affected by the dredging operation. The subsystem and dimensions were 1640 feet (0.5 km) compared with the 6560 feet (2 km) grid size of the hydrodynamic model.

Field data collected in an independent study (13) were used to verify the model results. The field data were collected in May 1972 for the purpose of measuring the extent of sediment transport and deposition adjacent to a dredge discharge line. The dredge location was in the central bay (Figure 49). Comparison of suspended sediment concentrations as a function of distance from the dredge discharge indicates good agreement between the model predicted results and actual field data (Figure 50). There was no noticeable level of sediment in the water column beyond station 5; a distance of 5000 feet from the dredge discharge in a north-northeasterly direction. This is attributed to a change in the bay current pattern from near flood tide to near high water slack in which current velocities decrease rapidly to levels less

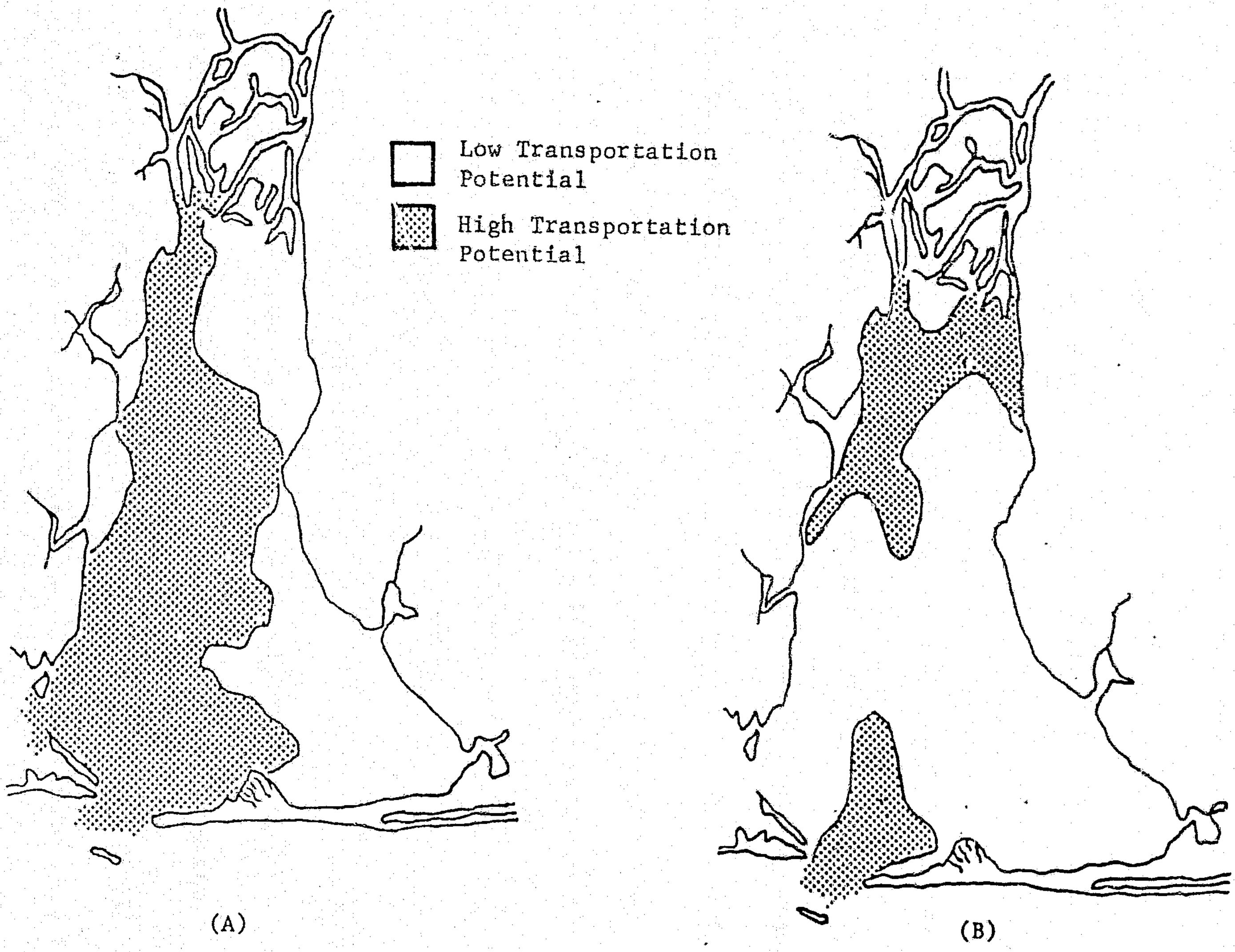


Figure 47. Schematic Diagram Illustrating the Impact of Channel Construction on Bay Transportation Potential at High River Flow Conditions; (A) No Channel, (B) Channel.

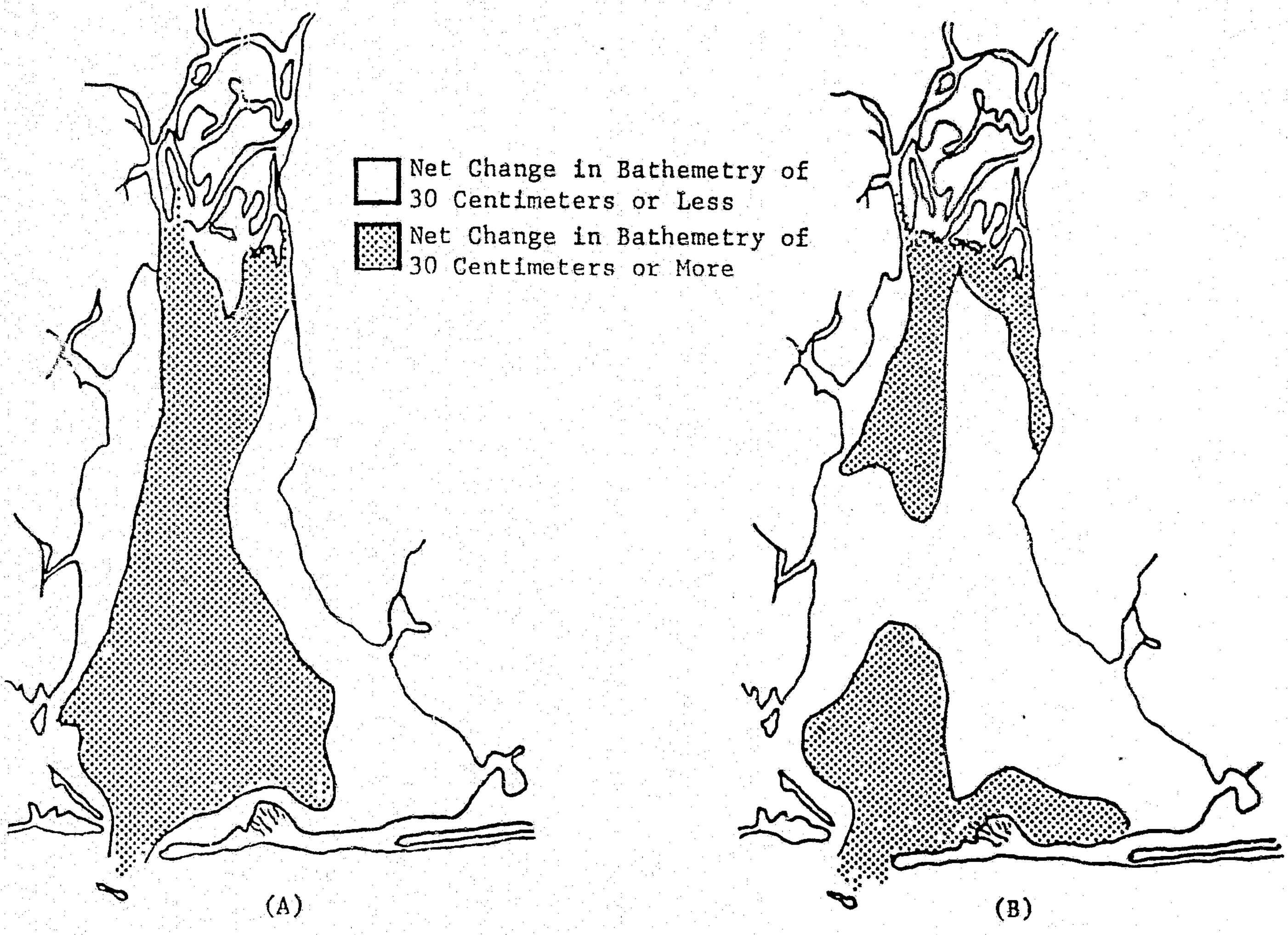


Figure 48. Sediment Deposition Trends as Reflected by Bay Bathymetric Data for the Periods (A) 1852-1920 and (B) 1920-1973 (Sapp, 1975).

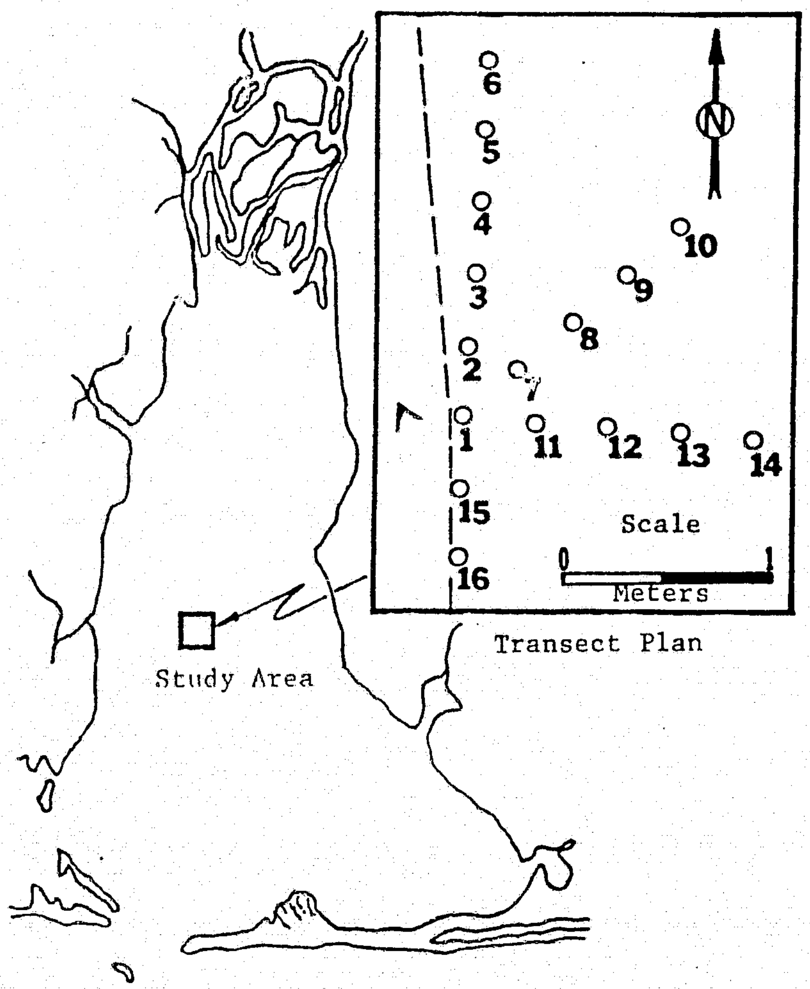


Figure 49. Location Map and Transect Plan for Maintenance Dredging Program (Brett, 1975).

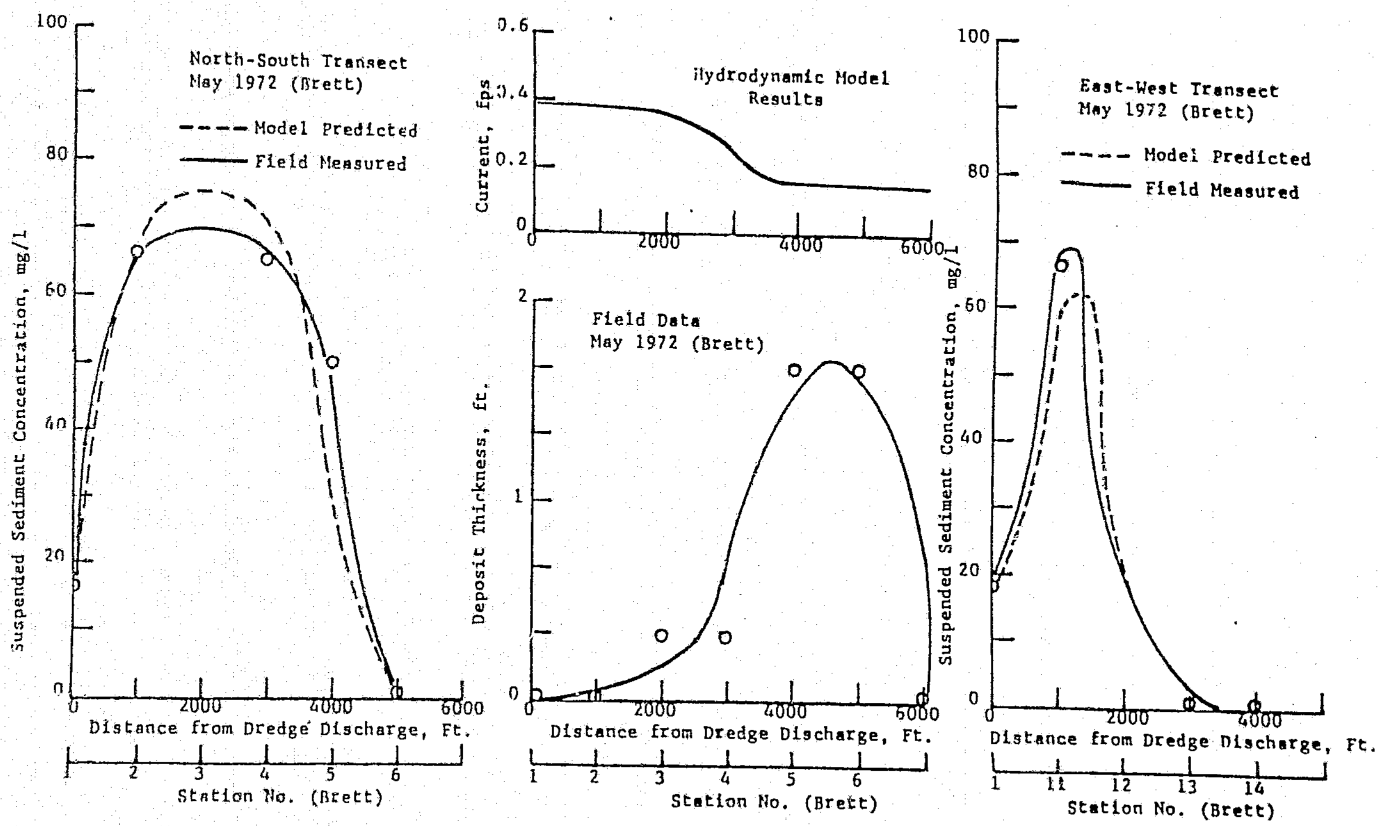


Figure 50. Comparison of Model Calculated (Dash) and Field Measured (Solid) Results for Maintenance Dredging Program (Brett, 1975).

than 0.2 ft/sec. Similar conclusions can be derived by considering the thickness of deposited material along the north-south sampling transect (Figure 50).

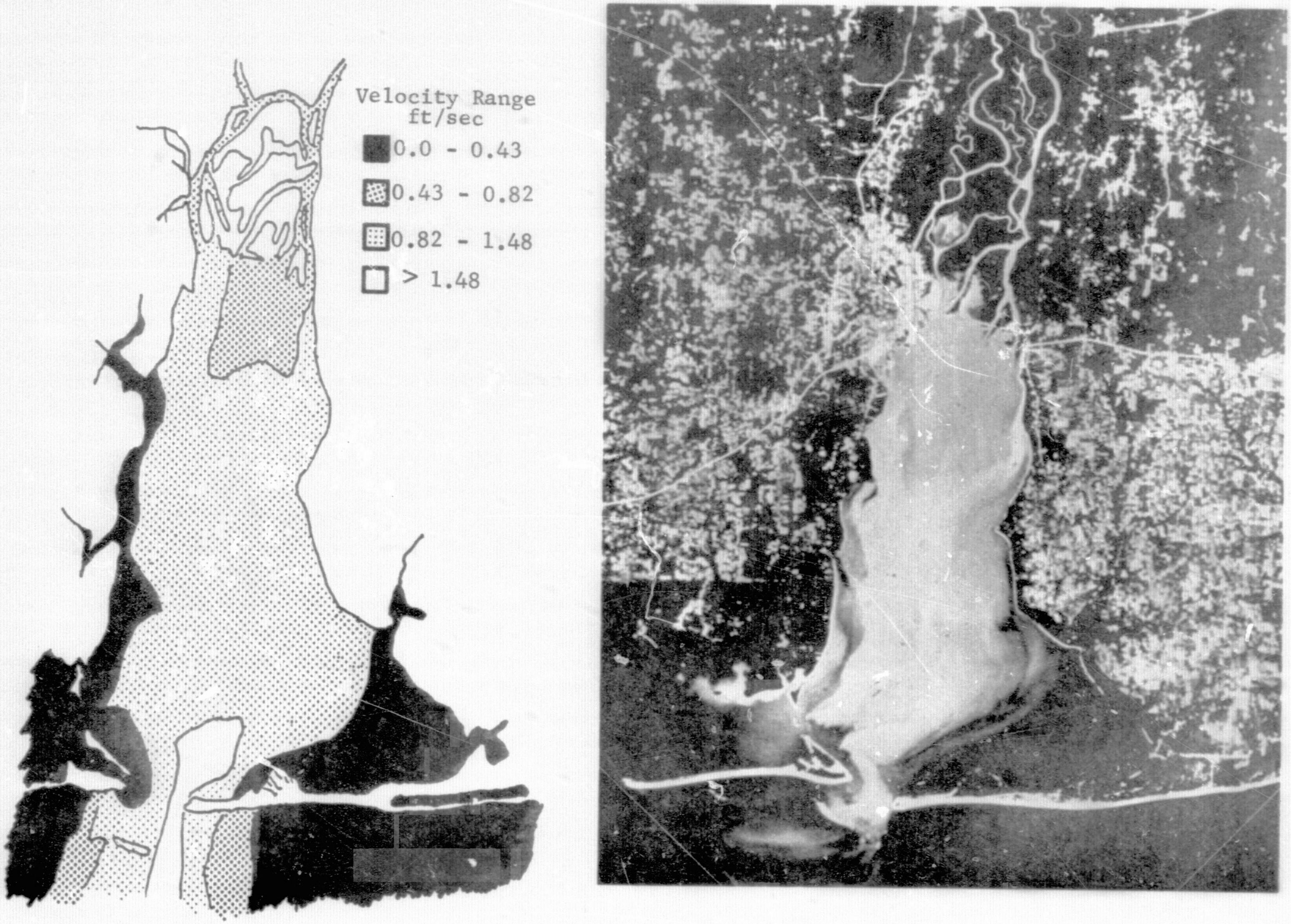
As the tide enters high water slack, the sediment transport was shifted from a north-northeasterly direction to a more easterly direction. Similar patterns were observed as those discussed during the flood tide condition. However, because of the low current velocities, the dredging discharge rate becomes an important source of energy for transportation during this period. Thus the nature of the deposition patterns was such that this material was deposited over a shorter distance (Figure 50). These observations are consistent with the lower velocities and shorter period of time that occur during the slack water condition.

Similar patterns to those experienced during flood tide and high water slack conditions were postulated for ebb tide and low water slack. More material will be transported over a longer distance as a consequence of the longer period of high current velocities in the ebb flow direction. During seasonal periods when river flow rates are smaller than the value investigated in this study, a smaller area will be affected as a result of the more uniform ebb/flood tidal relationship. Because of the river inputs, the ebb tide condition is always greater than the flood conditions except during unusual periods.

Naturally Occurring Sediment Transportation Events - The relationship of sediment transportation patterns to the hydrodynamic properties of Mobile Bay is shown by comparing model predicted velocity profiles with satellite photographs (Figure 51). In the case shown the hydrodynamic model was run at the local conditions observed during the photographic mission over the bay. The resulting velocity vectors were then reduced by a density slicing method where the following criteria were applied:

Category	1	2	3	4	5
Velocity Range ft/sec	0-0.43	0.43-0.82	0.82-1.48	1.48-2.95	2.95-4.10

It should be noted that this method is highly acceptible when there is high sediment loads within the bay in which hydrodynamic factors constitute the primary driving force.



(A) (B)

Figure 51. Comparison of Sediment Transportation Patterns Predicted by the Hydrodynamic Model (A) and Skylab IV Photograph taken January 21, 1974 (B).

WATER RESOURCES PLANNING
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TECHNOLOGY TRANSFER

TECHNOLOGY TRANSFER

Output Format

During the course of the previously described investigations, emphasis on getting the results to potential users was a primary consideration. From the outset it was planned to present model results in a form easily identified with the Mobile Bay system. This was achieved by outputting the computer results for current, salinity, coliform bacteria and sediment distributions in the configuration of the bay (see Figure 52). This allows the rapid comparison of system behavior as a function of general location within the system.

Report Distribution

All of the reports were distributed to interested state, regional and federal agencies who could use the results provided. A listing of these agencies and the distribution for each of the interim reports is shown in Table 22. All of these reports were issued using contract funds with no expense to the agency receiving/requesting the document. On several occasions contacts were made by the principal investigator either by telephone or personal visits to the agency offices. This was especially the case for state and regional agencies with related water resource or quality interests.

Related Methods of Communicating Contract Findings

In addition to the interim report distributions, technology transfer was also achieved by several other methods. These included articles published in technical journals, presentation of results at local, regional or national/international meetings, conferences and workshops, and, seminars and interviews with various news media personnel. A listing of these activities are included in Table 23. In cases where results were presented at regional or national/international meetings, conferences and workshops, expenses were shared between contract funds and University funds designated to provide participation opportunities for faculty and research staff.

HEIGHT FROM REFERENCE PLANE TO SURFACE

38						1.37	.00	.00	.00	.00	.59							
37						1.30	.00	.00	.00	.00	.55							
36						1.17	.00	.00	.00	.00	.51							
35						1.05	.00	.00	.00	.00	.50							
34						.95	.00	.00	.00	.00	.50							
33						.89	.00	.00	.00	.00	.51							
32						.89	.00	.00	.00	.00	.53							
31						.91	.00	.00	.00	.00	.55							
30						.93	.00	.00	.00	.00	.59							
29						.96	.00	.00	.00	.00	.65							
28						.97	.97	.98	.98	.91	.72							
27					.94	.97	.96	.97	.97	.96	.95							
26					.93	.97	.97	.98	.98	.98	.98							
25					.97	.98	.98	.98	.99	1.00	1.04							
24					.99	.99	.98	.99	1.00	1.06	1.08							
23				.97	.98	1.00	1.01	1.03	1.08	1.10	1.11							
22				1.00	1.01	1.03	1.06	1.12	1.14	1.14	1.16	1.19						
21				1.03	1.06	1.06	1.14	1.14	1.16	1.16	1.18							
20			1.07	1.08	1.09	1.13	1.15	1.15	1.16	1.17	1.20							
19			1.09	1.10	1.13	1.14	1.16	1.16	1.15	1.16								
18			1.11	1.12	1.13	1.14	1.17	1.17	1.15	1.15								
17			1.08	1.10	1.12	1.12	1.17	1.17	1.16	1.14	1.15							
16			1.07	1.08	1.10	1.11	1.15	1.15	1.15	1.13	1.13							
15			1.08	1.08	1.09	1.09	1.12	1.14	1.13	1.14	1.13							
14			1.07	1.07	1.07	1.06	1.09	1.11	1.14	1.13	1.13	1.13						
13			1.04	1.05	1.05	1.05	1.05	1.08	1.11	1.11	1.12	1.11	1.10					
12			1.02	1.03	1.03	1.03	1.02	1.06	1.08	1.09	1.09	1.12	1.10	1.08	1.05			
11		.97	.99	1.02	1.03	1.03	1.02	1.05	1.07	1.07	1.07	1.09	1.11	1.09	1.09			
10		1.00	1.00	1.01	1.01	1.03	1.03	1.02	1.06	1.06	1.07	1.07	1.11	1.11	1.13	1.17		
9	1.00	.98	.98	.99	.99	1.01	1.02	1.03	1.04	1.08	1.07	1.08	1.09	1.11	1.16	1.17	1.17	
8	1.20	1.01	.97	.96	.98	.99	1.02	1.06	1.02	1.06	1.09	1.07	1.09	1.11	1.14	1.14	1.13	1.10
7		.97	.95	.94	.96	.99	.99	1.04	1.06	1.05	1.07	1.07	1.10	1.10	1.08	1.05	1.03	1.02
6			.93	.88	.90	.91	1.01	.97	1.03	1.05	1.09	1.11	1.13	1.12	1.05	.97	.96	.97
5				.76	.80	.84	.92	.97	.98			1.16	1.19	1.20				
4	.59	.59	.64	.61	.68	.72												
3	.57	.60	.58	.63	.64	.63	.64	.59	.56	.59								
2	.59	.61	.62	.64	.66	.61	.62	.59	.59	.59								
1	.60	.57	.59	.55	.59	.55	.57	.57	.58	.56								

Figure 52. Typical Computer Output for Mobile Bay Calculations (Vertical Direction Suppressed 2 to 1).

Table 19. - Distribution List of Contract Reports to State Agencies and Other Interested Groups (excluding NASA/MSFC Distributions).

BER No.	168-112	169-112	174-112	185-112	203-112	208-112	209-112
Report Subject	Hydrodynamic and Salinity (Condensed)	Hydrodynamic and Salinity (Interim	Coliform Bacteria (Preliminary)	Coliform Bacteria (Interim)	Hydrodynamic (Users' Manual)	Sediment Transport (Interim)	Mobile Bay Models (Final)
Agency or Group Name:							
State:							
Alabama Water Improvement Commission	IC	-	RC	-	-	-	IC
Alabama Conservation Department	IC(2)	-	-	IC	-	-	-
Alabama Highway Department	IC(2)	-	-	IC(2)	-	-	-
Alabama Geological Survey	IC	RC	-	IC	-	IC	IC
Alabama State Health Department	IC(2)	-	RC(2)	IC(3)	-	-	IC
Marine Environmental Sciences Consortium	RC(5)	RC(3)	IC	IC	-	RC(2)	IC(2)
South Alabama Regional Planning Commission	IC	-	-	-	-	-	IC
Federal:							
United States Environmental Protection Agency	-	-	RC	-	-	-	IC
United States Corps of Engineers							
Mobile District	IC(2)	-	-	-	IC	IC	IC
New Orleans District	IC(2)	-	-	IC(2)	-	-	IC
Vicksburg (WES)	IC	-	-	-	IC	-	IC
United States Fisheries and Wildlife Service	IC	-	IC	-	-	-	-
United States Hygiene Laboratory (Dauphine Island)	IC	-	-	-	-	-	-
Regional:							
Central and Southern Flood Control (Florida)	-	-	-	-	RC	-	-
Tri-State Regional Planning Commission (New York)	-	-	-	RC	-	-	-
Alabama-Mississippi Seagrant Office	IC	-	-	-	-	-	-
Universities:							
The University of Alabama							
Bureau of Engineering Research	IC	IC	IC	IC	IC	IC	IC
Chemical and Metallurgical Engineering	IC	IC	IC	IC	IC	IC	IC
Engineering Library	IC	IC	IC	IC	IC	IC	IC
Natural Resources Center	IC(2)	-	-	IC	IC	IC	IC
Contracts and Grants	IC	IC	IC	IC	IC	IC	IC
Auburn University	IC	-	-	-	-	-	-
Birmingham Southern University	RC	-	-	-	-	-	-
Calvin College	RC	-	-	-	-	-	-
Louisiana State University	RC	RC	-	-	-	-	-
Mississippi State University	IC	IC	-	RC	RC	-	IC
Private:							
Amoco International	-	-	-	-	IC	-	-
Environmental Consultants International	RC	-	-	-	-	-	-
Mobile Oil	RC	-	-	-	-	-	-
PPG Industries	RC	-	-	-	-	-	-
Poly Engineering (Mobile)	IC	-	-	-	-	-	-
Snowy Mountain Engineering Corporation	-	-	-	-	RC	-	-
	37	10	10	17	11	9	16

IC - Denotes Information Copy
RC - Denotes Requested Copy

Table 23. Transfer of Technology Developed Under NAS8-29100 via The Public Media.

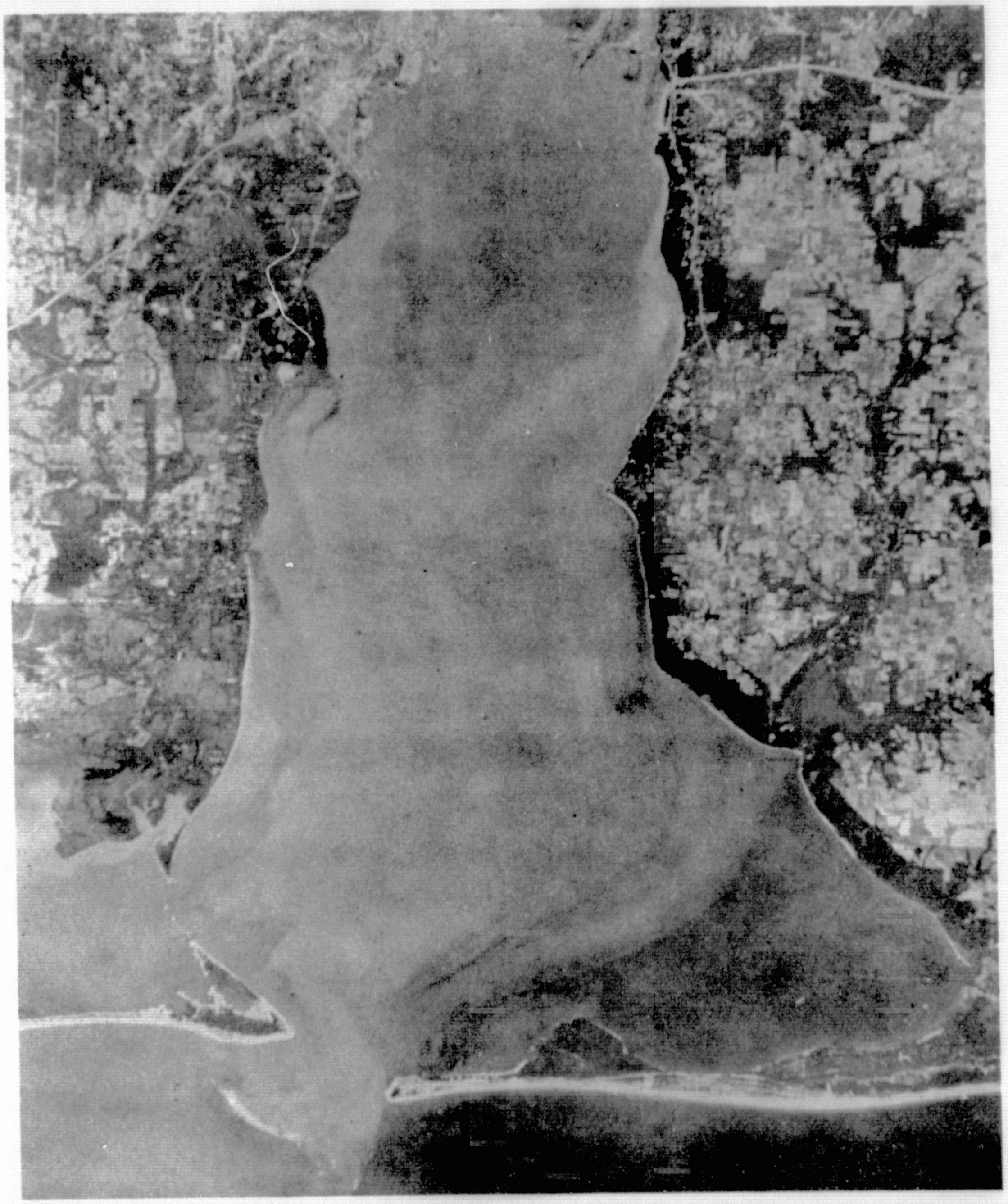
Description of Entry	Author(s)	Where	Date
Publications(7):			
"Legal Considerations of Water Pollution in Alabama"	April, Hill	J. of Marine Science, 2 (2)	1973
"Adaptation of Mathematical Modeling Techniques to Mobile Bay for Water Quality Management"	April, Hill	J. of Marine Science, 2 (2)	1973
"Hydrodynamic and Material Transport Model for Mobile Bay, Alabama"	April, Hill, & Liu	Symp. on Modeling Techniques	September 1975
"Mobile Bay Hydrodynamic and Material Transport Mathematical Modeling: The Importance of the Data Collection Base"		Remote Sensing Data Users' Conference	December 1975
"Predicting Material Transportation and Distribution in Mobile Bay"	April, Hill, Ng, Liu	ASCE Specialty Conference	January 1976
"Effects of Maintenance Dredging on Sedimentation in Mobile Bay, Alabama"	April, Brett	WODCON VII Conference	July 1976
"Sediment Transport and Deposition Model for Mobile Bay, Alabama"	April, Brett, Ng	15th International Conference	July 1976
Reports(7):			
"Water Resources Planning for Rivers Draining Into Mobile Bay. Part I: Hydrodynamic and Salinity Models,"	April, Hill	BER Report No. 168-112	January 1974
"A Hydrodynamic and Salinity Model for Mobile Bay"	April, Hill	BER Report No. 169-112	May 1974
"Verification of the Non-conservative Species Model for Coliform in Mobile Bay"	April, Liu	BER Report No. 174-112	June 1974
"Water Resources Planning for Rivers Draining Into Mobile Bay. Part II: Non-Conservative Species Transport Mobel"	April, Liu	BER Report No. 185-112	January 1975

Table 23 (Continued)

Description of Entry	Author(s)	Where	Date
Reports (Continued):			
"Water Resources Planning for Rivers Draining Into Mobile Bay. Users' Manual for the Two Dimensional Hydrodynamic Model"	April, Ng	BER Report No. 203-112	January 1976
"Water Resources Planning for Rivers Draining Into Mobile Bay. Sediment Transportation and Distribution Patterns"	April, Ng	BER Report No. 208-112	December 1976
Presentations (6):			
"A Hydrodynamic and Salinity Model for Mobile Bay, Alabama"	April, Hill	77th National Meeting of AIChE	June 1974
"A Hydrodynamic and Material Transport Model for Mobile Bay, Alabama"	April, Hill, Liu	Symp. on Modeling Techniques	September 1975
"Predicting Sediment Transport and Deposition Patterns in Mobile Bay, Alabama"	April, Brett	Inter. Symp. on Dredging Tech.	September 1975
"Predicting Material Transportation and Distribution in Mobile Bay"	April, Hill, Ng, Liu	ASCE Specialty Conference	January 1976
"Effects of Maintenance Dredging on Sedimentation in Mobile Bay, Alabama"	April, Brett	WODCON VII Conference	July 1976
"Sediment Transport and Deposition Model for Mobile Bay, Alabama"	April, Brett, Ng	15th Inter. Conference	July 1976
Seminars (8):			
"Math Modeling Estuarine Bodies"	April	Auburn University	May 1971
"Modeling Mobile Bay - An Overall Plan"	April	Ala. Marine Science Inst.	July 1971

Table 23 (Continued)

Description of Entry	Author(s)	Where	Date
Seminars (Continued):			
"Engineering in the Marine Environment"	April	Tuskegee Inst.	April 1973
"Mobile Bay Mathematical Modeling"	April	The U of A	March 1975
"Mobile Bay Modeling"	April	The U of A	March 1975
"Modeling an Unconventional Reaction System - Mobile Bay, Alabama"	April	U. of Tenn.	November 1975
"Material Transport in Estuarine Systems - The Mobile Bay Experience"	April	Miss. St. U.	March 1976
"Predicting Material Transport in Mobile Bay"	April	The U of A	April 1976
Short Courses & Conferences (2):			
"A Model of Mobile Bay, Alabama Consortium of Higher Education"	April	ETV Series: Environment	October 1973
"Mobile Bay Hydrodynamic and Material Transport Mathematical Modeling: The Importance of the Data Collection Base"	April	Remote Sensing Data Users' Conference	December 1975
Interviews (2):			
"Modeling Mobile Bay"	April	Capstone Comments	August 1973
"How Will Storms Affect Mobile's Tides?"	April	B'ham News	November 1974
Student Related Activities (4):			
"A Hydrodynamic and Salinity Model for Mobile Bay"	Hill	Ph.D. Dissert.	1974
"Development of Hydrodynamic and Material Transport Model Interface"	Slocovich	M.S. (non-thesis)	1974
"A Non-Conservative Species Transport Model for Mobile Bay"	Liu	M.S. Thesis	1975
"Predicting Sediment Transportation in Mobile Bay"	Ng	M.S. Thesis	1976



WATER RESOURCES PLANNING FOR RIVERS DRAINING INTO MOBILE BAY

CONCLUSIONS

CONCLUSIONS

Models for the prediction of hydrodynamic, salinity, coliform bacteria and sediment behavior have been developed for Mobile Bay. These models allow for: (1) variability in grid size to obtain the desired detail in water-land boundaries, dynamic boundaries and other points of interest within the system, (2) the effect of the earth's rotation, (3) effects of rapidly changing velocities, (4) the variability in bottom friction, (5) resistance created by spoil banks, (6) variability in fresh water flow, (7) effect of wind conditions, (8) effects of the salinity wedge, (9) variability in the total coliform source concentration of several locations, (10) variability in water temperature as related to coliform bacteria dieoff rate constants, and (11) long and short range sediment transport and deposition trends. These paradigms are based on established engineering practice and available data sources, and constitute the necessary framework for the development of other models and data collection programs in support of projects related to water quality and water resource assessment for rivers draining into Mobile Bay.

Programs for the digital computation of these models present outputs in a form conducive to rapid interpretation, have simple boundary conditions, and require minimum effort for utilization. Predictive capabilities are consistent with expectations and are adequate for trend analyses. These analyses may include the assessment of man's activities on bay behavior involving proposed dredging operations, spoil island construction, and pollution discharge locations to take advantage of optimum flushing characteristics of the bay. The models can also be used to study the impact that natural disturbances have on changes in land boundaries, wind and rainfall impacts; especially at levels approaching storm surge conditions.

WATER RESOURCES PLANNING
FOR
RIVERS DRAINING
INTO
MOBILE BAY

REFERENCES

REFERENCES

1. April, G. C. and C. E. Brett, "Predicting Sediment Transport and Deposition Patterns in Mobile Bay, Alabama," Paper E-3, 1st International Symposium on Dredging Technology, Canterbury, England, Sept. 17-19, 1975.

2. Ryan, J. J., "Sedimentologic Study of Mobile Bay," Department of Geology, Fla. State U., Tallahassee, Fla., June, 1969, 110 pages.

3. Hill, Donald O., and April, Gary C.,"A Hydrodynamic and Salinity Model for Mobile Bay," Report to NASAm The University of Alabama, BER Report No. 169-112, University, Alabama, May, 1974.

4. Hill, Donald O. and April, Gary C., "Water Resources Planning for Rivers Draining into Mobile Bay. Part I: Hydrodynamic and Salinity Models,: Report to NASA, The University of Alabama, BER Report No. 168-112, University, Alabama, January, 1974.

5. Barlow, John P., Jeffery, L. M. and Moskovits, George, Literature Survey of Lake Charles, La., Gulfport and Mobile, Alabama, and Pensacola, Fla., and Their Approaches, Vol. II, College Station, Texas, Texas A&M, Tech. Rep. 98-55-34F (Sept., 1955), 1-124.

6. National Aeronautics and Space Administration, ERTS (Earth Resources Technological Satellite) data received at The University of Alabama, Department of Civil Engineering, University, Alabama, Summer, 1973.

7. Hosty, H. S., "The Significance of EC Positive Organisms in Gulf Shellfish Growning Waters," (Private Communication to Dr. Gary A. April), January, 1974.

8. Bault, E. I., "Hydrology of Alabama Estuarine Areas - Cooperative Gulf of Mexico Estuarine Inventory," Alabama Department of Conservation and Natural Resources, Alabama Marine Resources Laboratory, Dauphin Island, Alabama Marine Resources Bulletin No. 7, February, 1972.

9. Liu, Hua-An and April, Gary C., "A Non-Conservative Species Transport Model for Mobile Bay," Report to NASA, The University of Alabama, BER Report No. 185-112, University, Alabama, January, 1975.

10. Chemical Rubber Company, "Handbook of Environmental Control Vol. III - Water Supply and Treatment," Cleveland, Ohio, CRC Press, 1973.

11. Espey, W. H., Jr., et al., "Galveston Bay Project Water Quality Modeling and Data Management, Phase II - Technical Progress Report," Report to Texas Water Quality Board, Austin, Texas, July, 1971.

12. Gallagher, T. P., et al., "Pollution Affecting Shellfish Harvesting in Mobile Bay, Alabama," Report to FWPCA, Athens, Georgia, August, 1969.

13. Brett, C. E., "Environmental Study of the Effects of Maintenance Dredging on Sediment Distribution in Mobile Bay, Alabama," The University of Alabama, University, Alabama, April, 1975, 25 pages.

14. Sapp, C. D., et. al., "Shoreline and Bathymetric Changes in the Coastal Area of Alabama - A Remote Sensing Approach," ALA-ADO-X996-CZMP-02, Geological Survey of Alabama, Tuscaloosa, Alabama, June 1975.

WATER RESOURCES PLANNING FOR RIVERS DRAINING INTO MOBILE BAY

APPENDICES

APPENDICES

Abstracts of Interim Reports Submitted to NASA/MSFC under Contract Number NAS8-29100.

BER Report No. 168-112

BER Report No. 169-112

BER Report No. 174-112

BER Report No. 185-112

BER Report No. 203-112

BER Report No. 208-112

INTERIM REPORT

on

Contract Number NAS8-29100

WATER RESOURCE PLANNING FOR RIVERS DRAINING INTO MOBILE BAY

PART I
HYDRODYNAMIC AND SALINITY MODELS

by

Donald O. Hill, Research Associate

and

Gary C. April, Principal Investigator

Prepared for

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

January 1974

BER Report No. 168-112

ABSTRACT

This study is the first step in the development of a comprehensive model for water quality measurements in Mobile Bay. Solution of the two-dimensional equations of change applied to Mobile Bay yields tide height, current patterns and salinity distribution profiles for varying river discharge rates (12,000-245,000 cfs) and prevailing wind conditions (0-25 knots, southwest). Pronounded effects are observed in the water movement of the Bay under the various conditions studied.

In addition to the above results, the developed models were verified with field data obtained by the U.S. Army Corps of Engineers and others. These verification studies were necessary to evaluate the effect of including Coriolis force and convective acceleration in the model equations. A modified method for estimating the bottom friction term produced savings in computational time at little loss in accuracy. Simulation of the salt wedge effect in the Bon Secour Bay region provided good agreement with observed isohalines without going to the expense of a three dimensional model.

The success of the hydrodynamic and salinity models obtained in this study has provided a good base from which BOD-DO models can be developed in subsequent investigations. These models will provide a baseline from which effects on the bay quality can be quantitatively measured.

INTERIM REPORT

on

Contract Number NAS8-29100

WATER RESOURCES PLANNING FOR RIVERS DRAINING INTO MOBILE BAY

A HYDRODYNAMIC AND SALINITY MODEL OF MOBILE BAY

by

Donald O. Hill, Research Associate

and

Gary C. April, Principal Investigator

Prepared for

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

May 1974

BER Report No. 169-112

ABSTRACT

The purposes of this research were to develop a hydrodynamic and salinity model for Mobile Bay, to study contributions of various terms in the equations developed and to evaluate the effects of certain natural phenomena. The equation of motion, the equation of continuity and the species continuity equations were reduced to two-dimensional form.

Due to the complexity of the partial differential equations involved, it was necessary to effect a numerical solution utilizing finite differencing. Equations in this form are amenable to computer solution. By superimposing a grid over the system, difference equations act on each finite element of the grid to determine an updated estimate of the solution. Successive grid sweeps are made until no significant change in the magnitude of the parameter being studied is evidenced. The computerized solutions of these basic partial differential equations constitute the hydrodynamic and salinity models for Mobile Bay.

Computing efficiency and perceptibility of computer output were of major consideration in the formulation of the Mobile Bay model. Specification of a constant river discharge at the northern end of the bay and inclusion of a marsh area above the causeway to act as a capacitance element simplified boundary conditions yet maintained a realistic result. A weir arrangement located along the two idealized river channels through the marsh permits drainage and overflow at specified tide heights. This procedure allows variation in river flow with only one simple change in river discharge and does not require a boundary change for changes in season, winds, or weather.

Standard computational techniques for determining resistance consume considerable time, assume a significant difference in the resistance between time t and $t + \Delta t$ and base the magnitude of the resistance term on the resultant of the x-y velocities. This investigation tested a modified computational approach for the friction terms with the following assumptions: the difference between t and $t + \Delta t$ is small ($\Delta t = 2$ min.) and the resistance in the x-direction is dependent only on the x-component of velocity. While not completely satisfactory in predicting tidal elevations, the method shows promise as a rapid, accurate step when dealing with the salinity model solutions.

The significance of convective acceleration terms and the Coriolis force has been considered in this research. Convective acceleration, in general, should be included where rapid changes in velocity are expected. Due to nonlinearity, an upstream differencing technique must be used to insure stability. The Coriolis force was shown to be significant as a force acting on the bay and should be retained in the model.

Development of a method showing the effects of a salt wedge in the salinity program made possible the predictions of salt transport without the excessive computing time and cost required in a three-dimensional model. Consideration of the salt wedge in the Bon Secour area gave an improved definition of isohalines at low fresh water flow conditions, but may introduce error at high river flows.

Various parameters such as river flows and wind conditions were studied. Since the model does not make allowances for certain marsh areas or other land areas that become flooded at extreme tidal conditions, the model is not recommended for wind velocities greater than twenty-five knots.

This study represents a first step in the development of a comprehensive model in the Mobile Bay area. Other studies could include analyses of many proposed activities in the area such as: industrial and commercial development, municipal and urban expansion, and recreational development. Hopefully, implications arising from this study can be implemented so that the protective system for the ecology can keep pace with the projected growth and industrial development in Alabama.

INTERIM REPORT

on

Contract Number NAS8-29100

WATER RESOURCES PLANNING FOR RIVERS DRAINING INTO MOBILE BAY

VERIFICATION OF THE NON-CONSERVATIVE SPECIES TRANSPORT MODEL FOR COLIFORM IN MOBILE BAY

by

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ABSTRACT

Total coliform group concentration data for Mobile Bay collected by the Alabama State Department of Health for the period from January 1962 to August 1962 are used for the purpose of verification of the Non-Conservative Species Model for Mobile Bay. These coliform group concentrations are obtained by analysis as described by the outline entitled "The Significance of EC Positive Organisms in Gulf Shellfish Growing Waters" included in the Appendix.

The model is verified on a monthly basis, i.e. monthly average conditions are used and the model results are tabulated and compared to the monthly average of actual data. The standard deviations of the actual data are also tabulated to show the spread of the actual data. Remarks on whether the calculated model results fall within the range covered by the actual data are also made as a complement to the comparison between the calculated result and the actual data.

The fact that the model predicts reasonable results as compared to the actual data is encouraging. However, the model will be further tested with more detailed actual data, covering a different period of time and will be refined in an extensive parametric study.

INTERIM REPORT

on

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WATER RESOURCES PLANNING FOR RIVERS DRAINING INTO MOBILE BAY

PART II:

NON-CONSERVATIVE SPECIES TRANSPORT MODELS

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ABSTRACT

The purpose of this research effort is to expand the mathematical modeling capabilities of the hydrodynamic and salinity models of Hill and April to include a description of non-conservative species transport in the Mobile Bay system. In so doing, the knowledge gained provides a clear insight into the effect that rivers draining into the bay have on water quality conditions.

Total coliform group bacteria were selected because of their relationship to commercial fishing ventures within bay waters. This item was also chosen on the basis of data availability sufficient for model calibration and verification. Results are presented as monthly average distributions corresponding to the data base used.

In addition to the above, a parametric study was also conducted. In this study river flow rates, wind conditions and bay system temperatures were investigated to determine their influence on the total coliform concentration patterns. Of these factors temperature and river flow rate had a pronounced effect on the concentration profiles, while wind conditions showed only slight effects. Shifts in concentration profiles as much as 8 kilometers were observed in extreme cases.

The effect of changing total coliform group loading concentrations at constant river flow rates and temperature was also investigated. As expected these loading changes had an appreciable influence on total coliform distribution within Mobile Bay.

Utilization of the Non-Conservative Species Transport Model to predict trend behavior in the Mobile Bay system is demonstrated. Continuing efforts to improve the data collection programs in support of mathematical modeling are encouraged to increase the utility and predictive capabilities of the models.

INTERIM REPORT

on

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WATER RESOURCES PLANNING FOR RIVERS
DRAINING INTO MOBILE BAY

A USERS' MANUAL FOR THE TWO DIMENSIONAL HYDRODYNAMIC MODEL

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ABSTRACT

In order to better understand and explain the complex, interactive effects influencing water movement and water quality in natural systems, several mathematical models based on the laws of conservation of mass, monentum and energy have been developed. Models describing the hydrodynamic and material transport behavior of Mobile Bay have been formulated and tested under a National Aeronautics and Space Administration, Environmental Applications Branch Contract (NAS8-29100).

This booklet shows the way in which the model describing water movement and tidal elevation is formulated, computed and used to provide basic data about the system. Mobile Bay is used in a case study with comments as to how the fomulations might be expanded or focused to describe other areas which qualify under the model restrictions and assumptions.

The hydrodynamic model, as it will be called throughout the booklet, is based on two-dimensional, unsteady flow equations. The water mass is considered to be reasonably mixed such that integration (averaging) in the depth direction is a valid restriction. Convective acceleration, the Coriolis force, wind and bottom interactions are included as contributing terms in the momentum equations. The equations which makeup the hydrodynamic model include the continuity, x-momentum and y-momentum equations (Table 1).

Table 1.--Mathematical Representation and Operational Modes of the Physical Models for Mobile Bay

Name	Equation Form	Results	Modes
Continuity	$\frac{\partial Q_x}{\partial x} + \frac{\partial Q_y}{\partial y} + \frac{\partial H}{\partial t} = -(R + E)$	Tidal Height	Tidal Cycle Daily Avg Monthly Avg Seasonal
Momentum x-Component	$\frac{\partial Q_x}{\partial t} + gD\frac{\partial H}{\partial x} = KV^2\cos\psi - fQQ_xD^{-2} + Q_x(2W\sin\varphi)$	x-Component of Surface Current	Tidal Cycle Daily Avg Monthly Avg Seasonal
y-Component	$\frac{\partial Q_y}{\partial t} + gD\frac{\partial H}{\partial y} = KV^2\sin\psi - fQQ_yD^{-2} + Q_y(2W\sin\varphi)$	y-Component of Surface Current	Tidal Cycle Daily Avg Monthly Avg Seasonal

Results can be calculated for unsteady flow when boundary conditions are available as a function of time (dynamic), or for quasi-steady flow when conditions are stable for a time period encompassing several tidal cycles or longer periods (i.e. weekly, monthly, seasonally or yearly averages).

The solution of the equations shown in Table 1, applied to Mobile Bay, have been used to investigate the influence that river discharge rate, wind direction and speed, and tidal conditions have on water circulation and holdup within the bay. Storm surge conditions, oil spill

transport, artificial island construction, dredging and areas subject to flooding are other topics which could be investigated using the mathematical modeling approach.

To understand how the model might be applied to these topics, this booklet is subdivided into four parts for the convenience of the reader. These are, in order:

- Basic Concepts in Applying the Hydrodynamic Model to a Real System
- Model Input Requirements
- A Detailed Illustration: Application to Mobile Bay
- Hydrodynamic Model: Program Listing

Each section will be discussed separately, however, it is advisable that they be covered sequentially during the first reading to reinforce the basic concepts needed to understand and apply the model.

INTERIM REPORT

on

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WATER RESOURCES PLANNING FOR RIVERS DRAINING INTO MOBILE BAY

SEDIMENT TRANSPORTATION AND DISTRIBUTION PATTERNS

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ABSTRACT

The transportation and deposition of sediment play important roles in understanding, analysing and planning water resources and drainage system programs for Mobile Bay. The material transport properties are affected by the hydrodynamic behavior of the water mass and the rivers draining into the bay. Channelization within the bay is also an important parameter that must be considered.

The study is divided into three parts corresponding to various data bases identified. The first study utilizes the turbidity levels in the bay water as a natural tracer. In this case general transport patterns are correlated with key hydrodynamic parameters such as river flow rates, wind conditions and bay dispersion(used as a measure of bay mixing).

The second part of the investigation is a localized study of sediment and turbidity properties near the Main Pass of Mobile Bay. Data collected under NAS8-30810 and directed by the Marine Environmental Science Consortium will be analysed statistically to produce weighted correlations between sediment concentration and/or turbidity and key physical parameters.

Thirdly, a localized investigation of sediment transportation near a maintenance dredge will be studied to assess the possible impact of man-induced disturbances. An idealized mixing reactor model will be used to calculate suspended sediment concentration as a function of dredge operating parameters and the bay river and tidal states.

In all studies data collected from field stations or from remote sensing missions will be used. Discussion of the interactive ability of the model with a wide variety of data bases will also be presented.

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